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Illustration by Lauren Rolwing

Why are sphynx cats hairless? →p93

FROM THE EDITOR

I have to admit, I don't like Twitter. As someone who works on a magazine, this feels like a bit of a confession, since the social media site is abuzz with journalists and editors keeping their audiences up-to-date on the stories that matter. I want to like it and I can see the point, but to me the medium feels broken.

The trouble is that the things that make the site great – brevity, trending hashtags and anonymity – also give rise to its worst facets. 280 characters means that complex debates become simplistic; trends mean that everyone has to have an opinion on everything; and anonymity has a habit of turning people sour. Ultimately the medium rewards those with the most polarising views, which usually means any attempt at debate leaves people on either side staring at a crater where the middle ground used to be.

Of course, there is a good side to Twitter. It can connect strangers with similar interests and causes, dissolving thousands of miles in a single click. And it's massively empowering in the way it helps those who can't leave their homes connect with the world at large. But nevertheless, it's hard to come away from the site without feeling angry nowadays. So the real question is – is the anger we see on Twitter bleeding into the real world? Are we all as angry in person as we seem to be online? Head to p54 to find out how social media seems to push our buttons…

Daniel Bennett

Daniel Bennett, Editor

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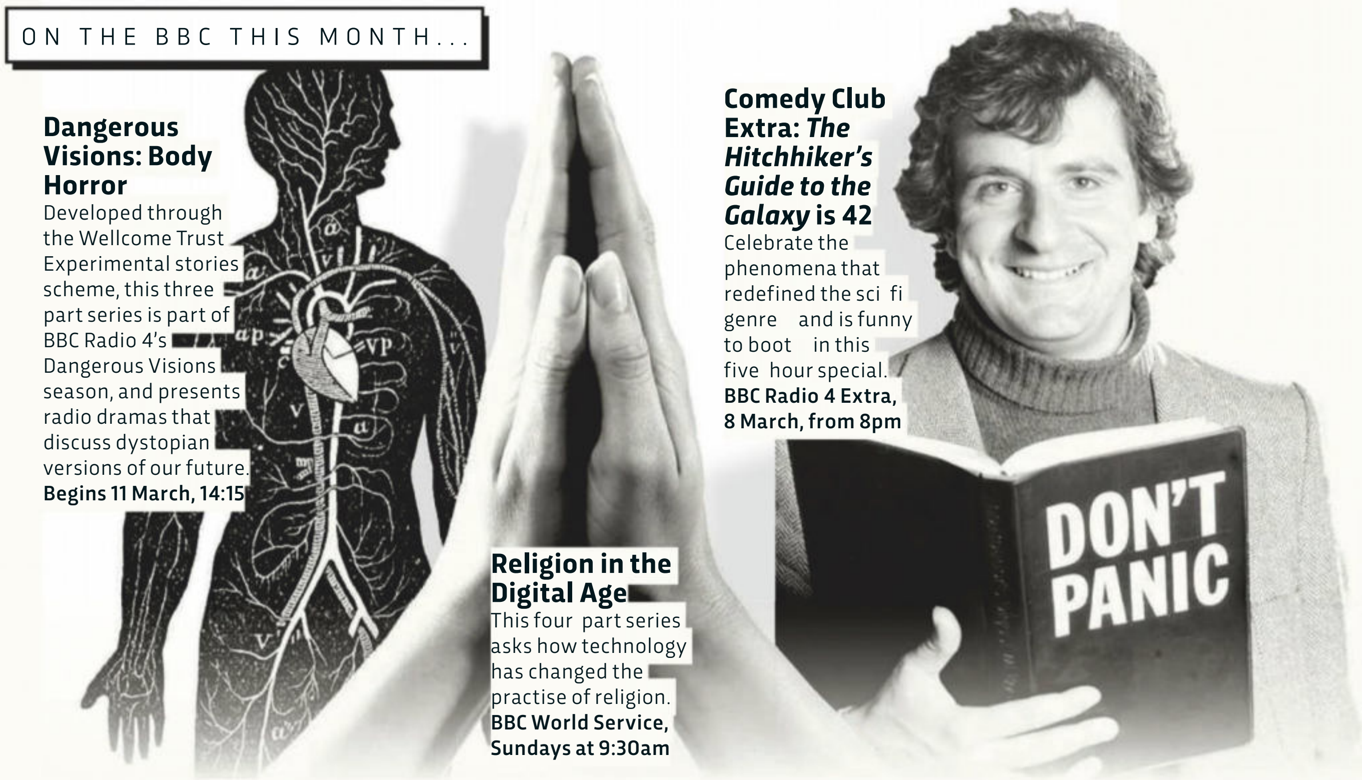
ON THE BBC THIS MONTH…



Dangerous Visions: Body Horror
Developed through the Wellcome Trust Experimental stories scheme, this three-part series is part of BBC Radio 4's Dangerous Visions season, and presents radio dramas that discuss dystopian versions of our future.
Begins 11 March, 14:15

Religion in the Digital Age
This four-part series asks how technology has changed the practise of religion.
BBC World Service, Sundays at 9:30am

Comedy Club Extra: *The Hitchhiker's Guide to the Galaxy* is 42
Celebrate the phenomena that redefined the sci-fi genre – and is funny to boot – in this five-hour special.
BBC Radio 4 Extra, 8 March, from 8pm

CONTRIBUTORS

DR EMILY LEVESQUE
Could the Betelgeuse star be about to explode? We asked University of Washington astronomer Emily, who studies the physics of supergiant stars. →P34

MARK MIODOWNIK
Is biodegradable plastic a waste of time? Materials scientist Mark Miodownik, one of the team behind the Big Compost Experiment explains why plastics aren't always a bad thing. → P32

BEN HOARE
Some animals have evolved to look like fresh faeces. To find out why, wildlife writer Ben journeys into the poo-niverse… →p48

DR CAMILLA PANG
Scientists are teaching machines to learn like us. But what can computers teach us about ourselves? Camilla tells us how science helped her create a guide to living with autism. →P60

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CONTENTS

REGULARS

06 EYE OPENER
Incredible scientific images from around the world.

10 CONVERSATION
Your letters, emails, texts and tweets.

15 DISCOVERIES
All the month's biggest science news. In this issue: how our microbiome could have allowed our species to spread; the feasibility of building a bridge between Scotland and Ireland; new research on the cause of migraines; cuttlefish cognition.

32 REALITY CHECK
The science behind the headlines. This month: Are compostable plastics any good? Is Betelgeuse about to go supernova? What's the deal with the Huawei 5G controversy?

38
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40 INNOVATIONS
The latest tech news and gadgetry.

67 ALEKS KROTOSKI
Meeting someone new? Be brave, and *don't* stalk them online first.

68 MICHAEL MOSLEY
Why lots of health testing could lead to needless worry.

89 Q&A
Our experts answer your questions. This month: Why are some people more squeamish than others? Is dog food safe to eat? How many bananas would I need to eat to become radioactive?

98 RADAR
Your guide to upcoming TV, exhibitions and radio.

104 NEXT MONTH
A sneak peek at what's in next month's *BBC Science Focus*.

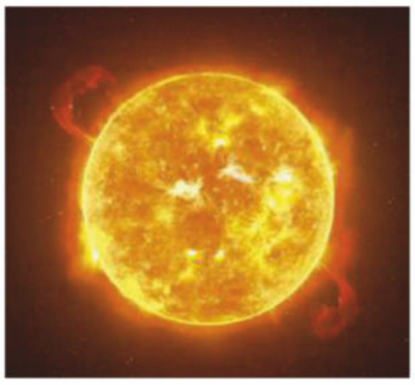
104 CROSSWORD
Our tricky cryptic crossword.

106 A SCIENTIST'S GUIDE TO LIFE
Get the lowdown on 'that time of the month'.

20
DISCOVERIES

Cuttlefish eat less for lunch when they know their favourite food is on the menu for dinner.

34
REALITY CHECK



Betelgeuse has changed shape and brightness. Is this supergiant about to go supernova?

48
OH, OOBEE DOO I WANNA BE LIKE POO
It turns out that disguising yourself as a smear of excrement is a pretty cunning way to hide.

FEATURES

48 **OH, OOBEE DOO I WANNA BE LIKE POO**
Wildlife that looks like poo.

54 **WHY ARE WE SO ANGRY?**
Is social media stoking our rage?

60 **INTERVIEW: DR CAMILLA PANG**
Why neurodiversity is so important.

70 **VITAL CLUES TO A THEORY OF EVERYTHING**
How mysterious ghost particles could help us understand the Universe.

76 **20 IDEAS YOU NEED TO KNOW ABOUT IN 2020**
The most important science and tech we can look forward to over the next year.

54

WHY ARE WE SO ANGRY?

76

20 IDEAS YOU NEED TO KNOW ABOUT IN 2020

60

INTERVIEW: DR CAMILLA PANG

> “I THINK EVERYONE IS NEURODIVERSE. EVEN THOUGH YOU TRY TO BE SQUARE, YOU’RE NOT SQUARE”

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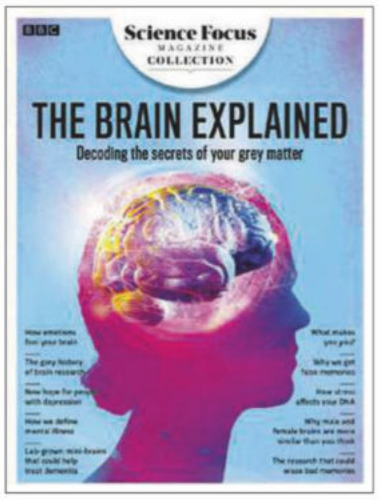

THE BRAIN EXPLAINED
In this special edition, brought to you by the team at *BBC Science Focus*, you can find out about the extraordinary abilities of the brain, its intriguing anatomy, the evolution of intelligence and the latest research into mental health.
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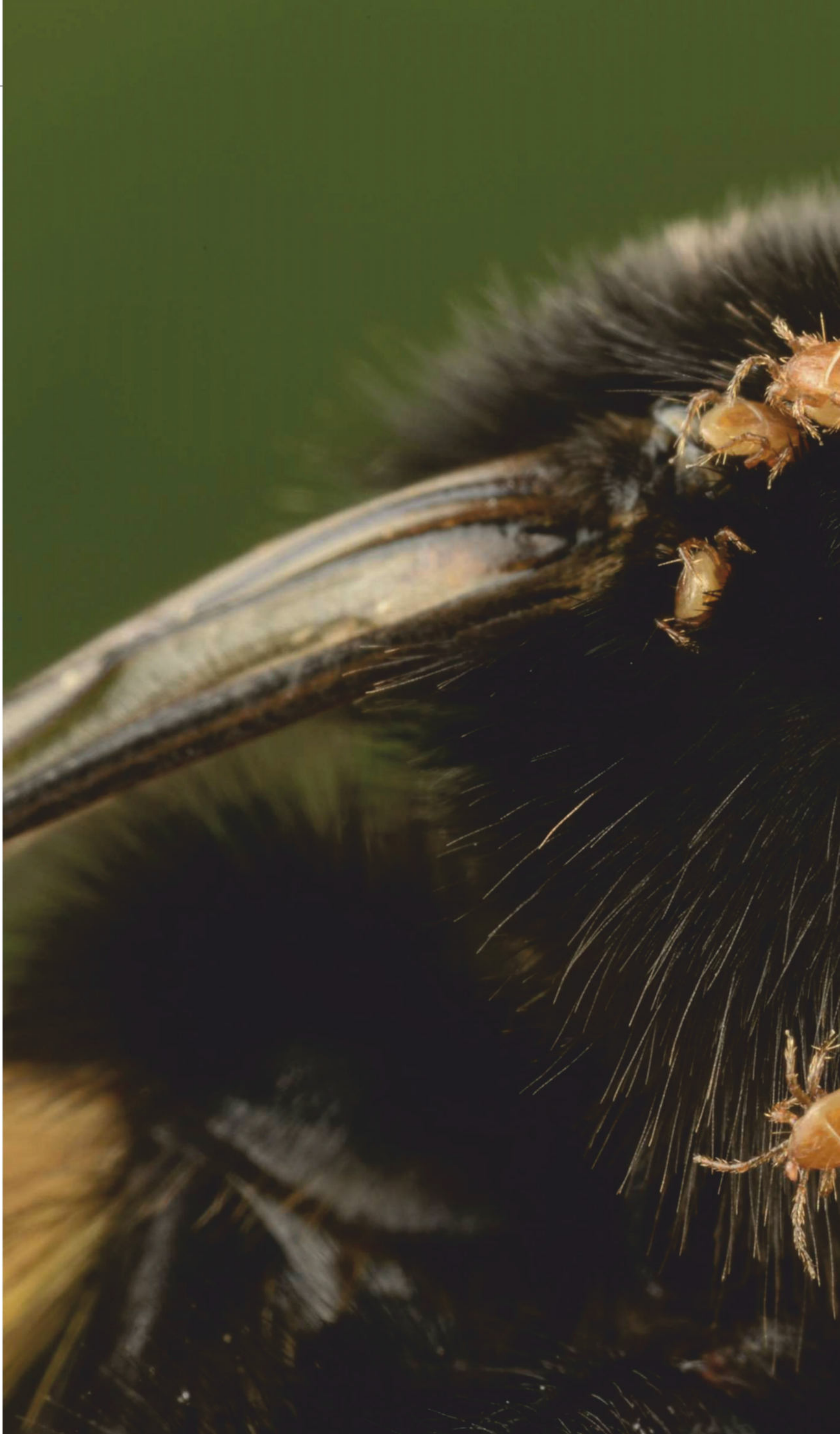
EYE OPENER

Oh, beehive

GOOSEFELD, GERMANY



This buff-tailed bumblebee is nature's Uber, carrying *Parasitellus* mites from nest to flower and back again. While the mites have no effect on the wellbeing of their host, the relationship isn't all that friendly.

"The mites are mostly kleptoparasitic. They steal pollen from the bees, and get shelter in the bee's nest," explains Professor Paul Schmid-Hempel, experimental ecologist and researcher into parasites and diseases of social insects at ETH Zürich, university for science and technology.

"They use the bee as a transport vehicle from one nest to another. They can also 'jump off' onto flowers that are visited by their carrier bee, then wait – up to maybe one day – for their next 'taxi' to jump on," he explains.

It's common to see large numbers of mites clinging to a single bee, especially a queen in the spring, as this is when she'll move on to establish a new nest.

HEIDI & HANS JÜRGEN KOCH

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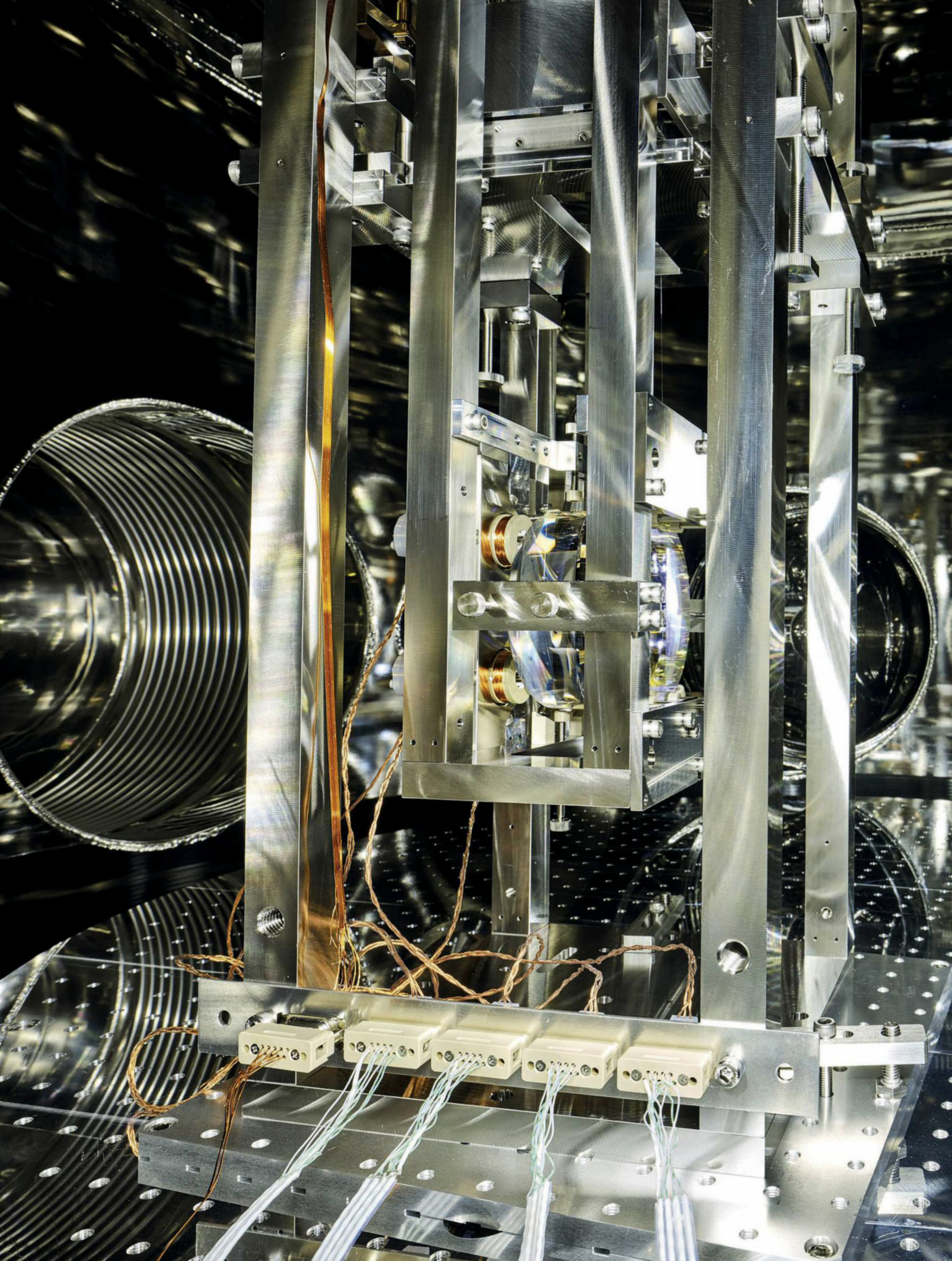

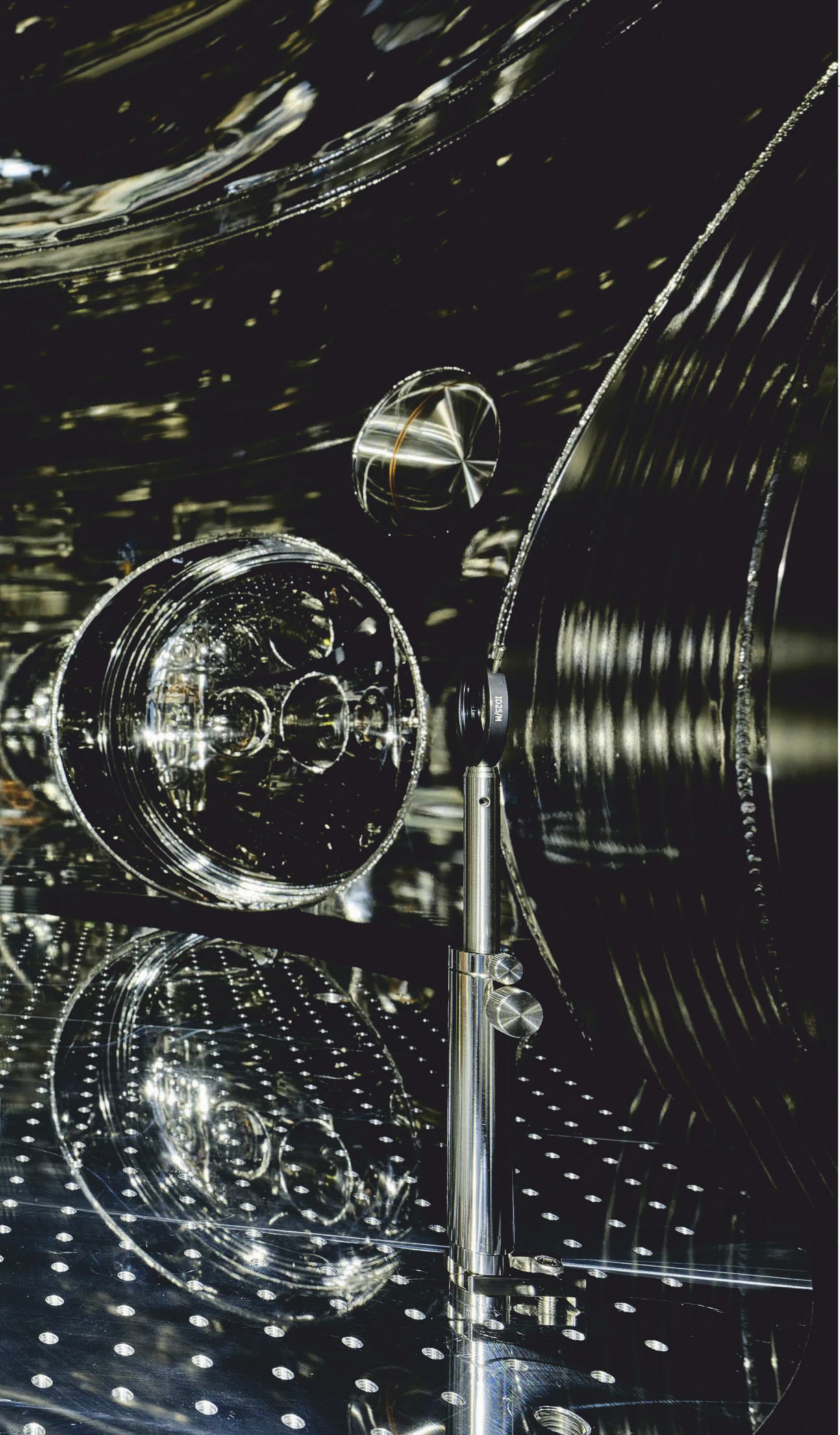

EYE OPENER

Time tunnels

IKENOYAMA, JAPAN

Deep in the abandoned Kamioka mine, is the world's most advanced gravitational wave (GW) detector. KAGRA is the first to be built underground, and the first to use cryogenically cooled mirrors. Two 3km-long arms branch out in an L shape. A laser, split in two, is sent hurtling down these arms and bounced between the super-cooled mirrors. When the beams are recombined and sent into the detector, their waveforms will align. That is, unless a passing GW has stretched or squeezed one of the arms. The beams' wavelengths will not line up, and the GW is detected. Yuta Michimura, Assistant Professor at the University of Tokyo, explains, "this is the vacuum chamber. It houses the fused silica mirror, OMMT2, which is curved to reduce the size of the beam impinging on the detection photo-diode. The walls of the entire chamber are precisely polished, to reduce the surface area. Too much surface area creates too much out gassing, and that isn't good for the vacuum."

ENRICO SACCHETTI

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LETTER OF THE MONTH

PUBLIC FOOTPATH

Finding solace in nature

The *Horizons* interview with Dr Alan Teo (February, p24) about *hikikomori* and social isolation was interesting.

My question is, could it be a reaction of some more sensitive individuals to the overcrowding that we constantly experience, especially in cities?

I have no desire to be in social isolation and I prefer to communicate in person rather than by phone, but I find it increasingly difficult to cope with crowded environments such as shopping centres and railway stations. So much so that I gave up going on overseas holidays in favour of quiet walks in the local countryside where one can see more animals than people.

Elena Holden, *via email*

Some individuals have anxiety, such as agoraphobia, where there is avoidance of these types of crowds and situations. That can undoubtedly contribute to social isolation. However, becoming a full-blown *hikikomori* would be a rather severe reaction to that.

Dr Alan Teo

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a pair of **Skullcandy Push True Wireless Earbuds**. Boasting water-resistance and 12 hours of battery, they also feature push controls on the buds, so you can leave your phone in your pocket. **skullcandy.co.uk**

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Deadly serious

In the Christmas issue, I read about the possibility of having babies without pregnancy (p56) and that death could be reversible (p57). These concepts taken together could raise a distinctly difficult scenario in the future.

Given the current population growth potential, could we ultimately reach a point where a future birth can only be justified by a death?

K Cherry, Nuneaton, *via email*

On the fly

Your photograph of the dead fly's unhappy encounter with the *Cordyceps* fungus (January, p6) should never have been published in a family magazine. The shock of it sent me into a dead faint, from which I recovered only after the administration of smelling salts and a necessarily generous glass of medicinal whisky.

I shall probably need counselling, but I am sure that, one day, I shall eventually recover from this horrifying experience.

Leo Kelly, New Zealand, *via email*

What, this one? Oh… sorry, Leo

Long trip

Stuart Clark's article about the effects of mining the Moon (January, p76) made for interesting reading, but didn't address the fundamental problem of the economics.

If I could find a petrol station where I could fill my car for 20p a litre, how far would it be worth driving to fill up? Similarly, if there were easily accessible supplies of lanthanum on the Moon, how expensive would it have to be on Earth before it was worth the expense of getting to the Moon, mining it and bringing it back?

Alan Blackwood, Stalybridge, *via email*

The brief answer is that a lot of what will be mined on the Moon will stay on the Moon. It will be used to help make the lunar base. As you correctly state, the transportation costs back to Earth would be enormous – at least initially.

If the Moon settlement becomes more established and travel between the Earth and the Moon becomes more commonplace, then we may see some return of material along with astronauts and that may pave the way to more commercial operations. It would be similar to the way in which commercial companies are now launching satellites for profit, where once it was thought to be too expensive to turn into an economically viable business.

Dr Stuart Clark,
BBC Science Focus
contributor

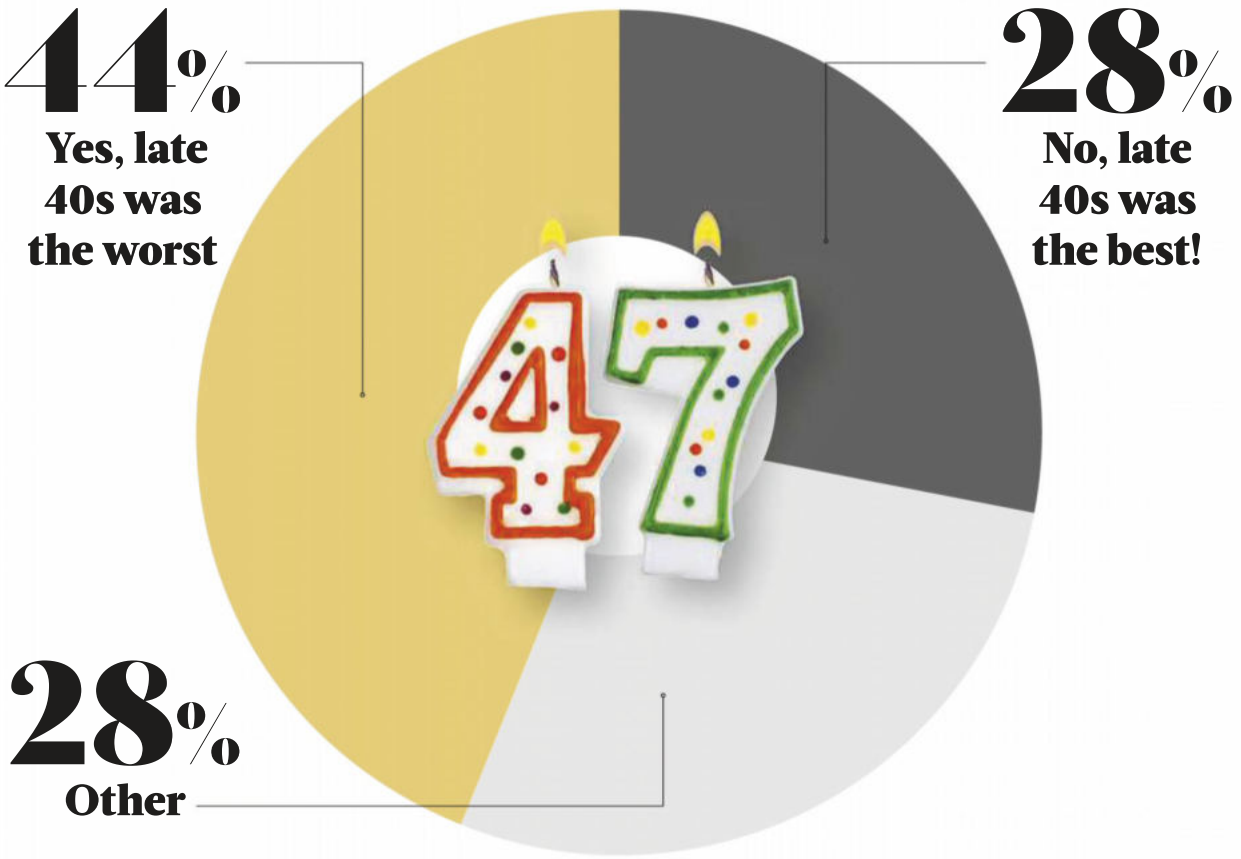
> *"SCIENCE IS STILL TEACHING ME. IT'S NOT A CONCRETE THING AND THIS IS ONE OF THE REASONS WHY I'M IN LOVE WITH IT. IT'S EVER-EVOLVING."*
>
> DR CAMILLA PANG, p60

READERS' BUZZ

Your views on the burning science topics of the month

Last month we discussed a recent study that showed our happiness tends to decrease towards midlife. We are most miserable at age 47.2, with happiness steadily increasing through our 50s and 60s. We asked our Facebook and Twitter followers if they agreed with the study's findings.

AN ECONOMIST HAS FOUND WE ARE MOST MISERABLE AT 47.2 YEARS OLD. DO YOU AGREE?



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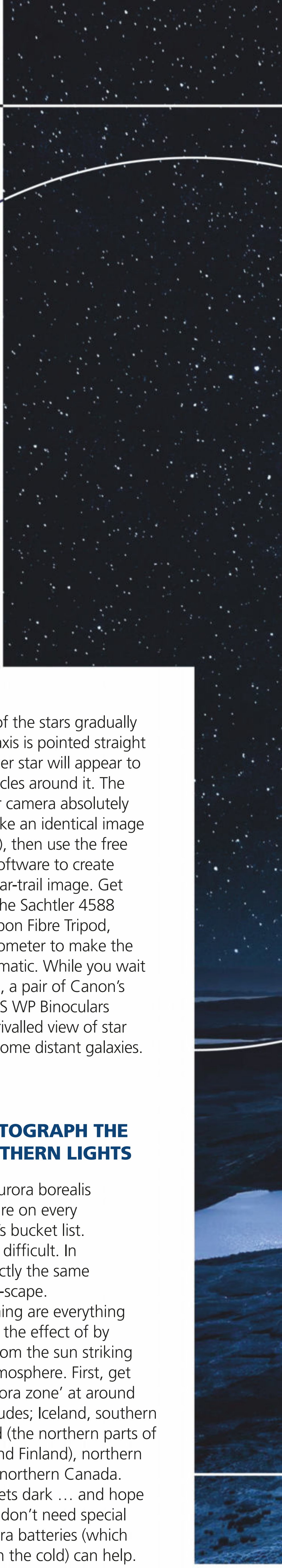
How to get *better pictures*

As spring arrives but spectacular starry sights of winter night sky still linger, discover these tips on targets and equipment you can source from MPB, the world’s best marketplace for used photo and video kit, so you can get the most from the galaxy of wonders above us



1

KNOW THE BASICS

Do you know the basic technique for photographing the night sky? It’s all about taking long exposures. With a DSLR or mirrorless camera on a tripod, put as wide-angle lens as you can get on manual focus, set it to infinity focus (the ∞ symbol), and set the aperture to as open-wide as it can get. That’s the lowest number it will go to (typically f/4.5 or f/2.8). Now choose ISO 800 and take a long exposure for about 20-25 seconds, recording it in a raw format for a large file size (a SanDisk Extreme memory card is handy here). If the photo is too dark, swap to ISO 1600, ISO 3200 or higher. Whatever camera you get, learn how to operate in a blackout, and understand that whatever you see on your camera’s LCD screen can be vastly improved upon in Photoshop.

2

FIND A DARK SKY

Capturing stars doesn’t have to be daunting, but it does have to be dark. Astrophotography is the art of collecting limited light – that of distant stars – which can be blotted-out easily by light pollution. The darkest locations include International Dark Sky Parks, International Dark Sky Reserves and Dark Sky Discovery Sites. However, the trick isn’t just to avoid artificial light. Many beginners forget all about one big light-polluter that can ruin astrophotography; the moon. It bleaches the night sky considerably, so avoid the week or so either side of the full moon. Useful apps include ‘ Dark Sky Finder’ and ‘Light Pollution Map’.

3

CAPTURE THE MILKY WAY

In the UK, the best time to capture the Milky Way is from May through to October. Prepare for summer by choosing a full-frame DSLR camera like Canon’s EOS 6D Mark II or the very latest and greatest Nikon Z6, Canon EOS R or Sony Alpha A9, which have very high ISO to detect more light while retaining a clean image. You can up your chances even further by using a wide-angle lens. Good pairings include the Fujifilm X-T3 and the Fujifilm 16mm f1.4 R WR lens, the Nikon Z6 and Nikon Nikkor Z 24mm f/1.8 S lens, the Canon EOS R and a Samyang MF 14mm f/2.8 (Canon RF Fit) lens. Or there’s the cream of the crop: the Sigma 14mm f/1.8 DG HSM Art lens for Canon, Nikon and Sony DSLR cameras. When summer arrives you’ll be ready to try for the bright heart of the galaxy. Download the brilliant ‘PhotoPills’ to help you line-up a shot in advance.

4

CREATE A STAR-TRAIL

It’s perhaps the most intoxicating kind of astro-photo out there, and it’s easy to do. With your camera pointed towards Polaris, the North Star, you can take multiple images that record how the positions of the stars gradually shift. Since Earth’s axis is pointed straight at Polaris, every other star will appear to make concentric circles around it. The trick is to keep your camera absolutely steady while you take an identical image 100 times (or more), then use the free StarStaX stacking software to create one mesmerising star-trail image. Get a study tripod like the Sachtler 4588 Speed Lock 75 Carbon Fibre Tripod, and use an intervalometer to make the entire process automatic. While you wait beside your camera, a pair of Canon’s incredible 10x42 L IS WP Binoculars will give you an unrivalled view of star clusters, and even some distant galaxies.

5

PHOTOGRAPH THE NORTHERN LIGHTS

The aurora borealis or northern lights are on every astrophotographer’s bucket list. The technique isn’t difficult. In fact, it’s almost exactly the same as taking any night-scape.

Location and timing are everything if you’re to capture the effect of by charged particles from the sun striking atoms in Earth’s atmosphere. First, get yourself to the ‘aurora zone’ at around 64°-70° North latitudes; Iceland, southern Greenland, Lapland (the northern parts of Norway, Sweden and Finland), northern Russia, Alaska and northern Canada. Then wait until it gets dark … and hope for clear skies. You don’t need special equipment, but extra batteries (which run down quickly in the cold) can help.

of the night sky

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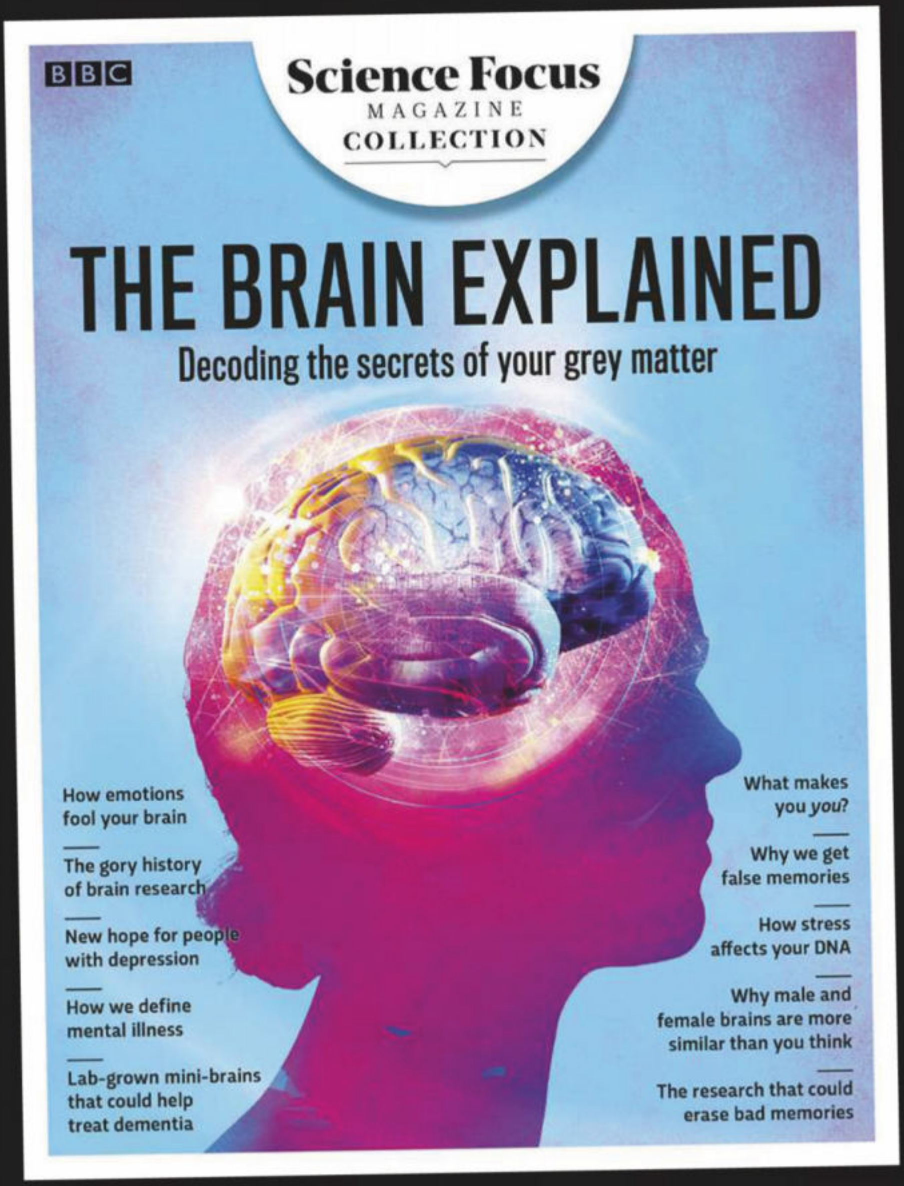
Decoding the secrets of your grey matter



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How we define mental illness

Lab-grown mini-brains that could help treat dementia

What makes you you?

Why we get false memories

How stress affects your DNA

Why male and female brains are more similar than you think

The research that could erase bad memories

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- What makes you ***you***?
- How to **build a brain**
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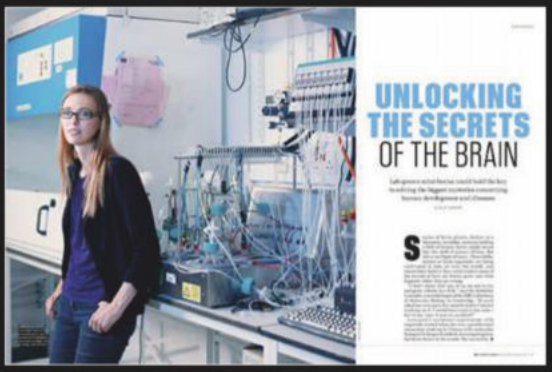

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NOT A HEADACHE New research improves migraine knowledge p17

A BRIDGE TOO FAR Could we build a bridge from Ireland to Scotland? p18

MAGIC MUSHROOMS Psychedelics boost cancer patients' wellbeing p19

SHRIMPY DINNER Cuttlefish eat less for lunch when shrimp's for dinner p20

DISCOVERIES

Illustration of bacteria in the human gut

GETTY IMAGES

HAVE GUT BACTERIA, WILL TRAVEL

Our ancestors' gut microbiome may have helped them adapt to new areas

Our feet may be made for walking but it's our gut bacteria that enabled us to spread so far around the globe, according to a new study carried out by a team of scientists at North Carolina State University in the US. The researchers suggest that our microbiome could have been the crucial factor that allowed us to adapt and survive in new locations. The hypotheses suggested by this study still need to be tested by palaeoanthropologists, ecologists and medical researchers, but Dr Rob Dunn, the biologist who led the team, hopes it will shift the emphasis of future research.

"We're hoping the findings will change some questions, and that other researchers will study ▶

Desert fish More than 10,000 years ago, there was water in the Sahara p21 **Bye bye, baby** World birth rates have declined since the 1960s p22 **Root of the problem** Planting a trillion trees may not be a good idea p24 **Pale blue dot** The story behind the image p26

News in brief

PLANTING BEES' FAVOURITE FLOWERS MAY HELP SAVE THEM

Bumblebee populations have declined in recent decades. One reason for this is a lack of flowers, and bees can be picky about the blooms they visit, according to research published in the journal *Environmental Entomology*. It was found that of 100 flower species, 14 were the preferred choice of the bees, with different bee species favouring different flowers. "This study allowed us to provide a concise, scientifically based list of important plant species to use in habitat restoration that will meet the needs of multiple bumblebee species and provide blooms across the entire annual lifecycle," said Helen Loffland, who took part in the research.

Our adaptable gut bacteria may have allowed us to colonise new environments

the consequences of changes in the human microbiome," said Dunn.

By using data from previously published studies of gut bacteria found in humans and other primates, the team found that there are big differences in the function and composition of a person's microbiome depending on their location, their diet and their lifestyle. They think that when our ancestors arrived in new places and encountered new foods, it was the adaptability of their gut bacteria that allowed them to detoxify and digest the food.

But the team also believes that our ancestors learnt to process food by employing the bacteria from their bodies to initiate the fermentation process. Similar methods are still in use today – bacteria in saliva are used to produce alcoholic drinks in Latin America, and skin bacteria are involved in the production of some soft cheeses and sourdough breads. By using their microbes to ferment certain meats, tubers and roots, our ancestors were able to enrich the vitamin content of these foods as well as preserve them for longer to provide a lasting source of nutrition in a particular location.

> "We outsourced our body microbes into our foods – that could well be the most important tool we ever invented"

"We outsourced our body microbes into our foods – that could well be the most important tool we ever invented. But it's a hard tool to see in the past and so we don't talk about it much. Stone artefacts preserve, but fish or beer fermented in a hole in the ground doesn't," said Dunn. "Hopefully the next decade will see more focus on microbes in our past and less on sharp rocks."

Dr Tim Spector, professor of genetic epidemiology at King's College London and author of *The Diet Myth*, echoes the sentiment. "The hypothesis that microbes helped our ancestors adapt to new environments is compelling, though hard to prove," he said. "Our gut microbes are the most unique and modifiable part of our bodies and will rapidly react to new foods and environment. We share only around 25 per cent of our microbes with each other compared to over 99 per cent of our genes, so it makes sense that we relied on them for the rapid adaptations needed as we expanded [our range]."

TRAVIS DUBRIDGE, KESHAB GOGOI, GETTY IMAGES X2 ILLUSTRATION: JOE WALDRON

They did what?

People shown horror films

WHAT DID THEY DO?
Researchers at the University of Turku in Finland put together a list of the 100 best horror films of the last 100 years, including classics such as *The Exorcist* and *The Devil's Backbone*. They showed them to a group of volunteers and measured their neural activity as they watched.

WHY DID THEY DO THAT?
They wanted to find out why humans are drawn to films that are purposefully designed to be as scary as possible, and how the brain deals with fear.

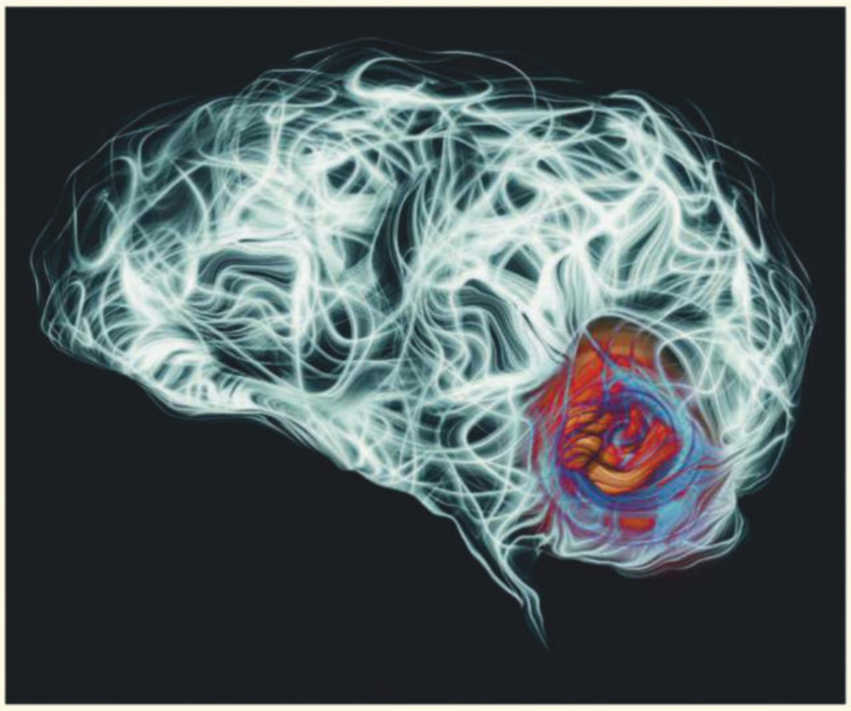
WHAT DID THEY FIND?
During periods in the films when the tension is slowly building, regions of the brain involved in visual and auditory perception become more active, as the need to look for cues of threat in the environment become more important. After a sudden shock or jump scare, brain regions involved in emotion processing, threat evaluation, and decision-making become more active, enabling a rapid response. However, both regions are in continuous communication with the sensory regions continuously preparing the response networks as a scary event becomes increasingly likely. Horror movies exploit this effect to enhance our excitement of them.

NEW ID METHOD IS THE CAT'S WHISKERS

The Wildlife Institute of India has designed a computer program that can identify Asiatic lions using their whisker patterns and body marks. Monitoring the species has helped it recover from a population of 50 to approximately 500, but existing counting methods leave a margin for error as some lions are counted more than once. To date, the new program has identified 67 individuals from 368 sightings. The team says their method could be used to monitor lions in India and Africa to improve conservation efforts.

BRAIN

Cause of migraines could be in sight



Migraine sufferers experience increased or extreme sensitivity to light and sound, and a new study from the University of Birmingham and the University of Lancaster could finally explain why.

Migraines are a neurological condition characterised by intense, debilitating headaches. An estimated six million people suffer from migraines in the UK – approximately 11 per cent of the population.

The study found that people who suffer from migraine headaches appear to have a hyper-excitable visual cortex, which is the part of the brain that receives, integrates and processes visual information from the retinas.

"Most migraineurs also report experiencing abnormal visual sensations in their everyday life, for example, elementary hallucinations, visual discomforts and extra light sensitivity," said lead author Dr Terence Chun Yuen Fong.

In the research, 60 volunteers – half of whom regularly suffered from migraines – had to rate a striped pattern according to whether it was uncomfortable to look at, and had to record any associated visual phenomena they experienced. A further EEG test was carried out, allowing researchers to track and record specific brain response patterns. Results from both tests agreed. A larger response to the striped pattern was found in the visual cortex among the group of migraine sufferers when compared to the non-migraine sufferers. However, the study also found hyper-excitability in the visual cortex in a subgroup of non-migraineurs; those who had reported additional visual disturbances but did not experience migraines.

"Our study provides evidence there are likely specific anomalies present in the way the visual cortex of migraine sufferers processes information from the outside world," said senior author Dr Ali Mazaheri. "However, we suspect it's only part of the picture since the same patterns of activity can also be seen in non-migraineurs who are sensitive to certain visual stimuli."

GOLF CAN HELP KEEP OLDER PEOPLE'S HEALTH ABOVE PAR

Playing golf at least once a month could lower the risk of death among adults aged 65 and older, according to the American Heart Association. Over the course of 10 years, the team analysed data from nearly 5,900 male and female participants with an average age of 72. Of the participants, there was a lower rate of death among the golfers compared to the non-golfers (15.1 per cent versus 24.6 per cent). The researchers say that golf offers benefits like social interaction, a competitive element and fresh air, and as it's a gentle form of exercise, people are able to continue taking part as they get older.

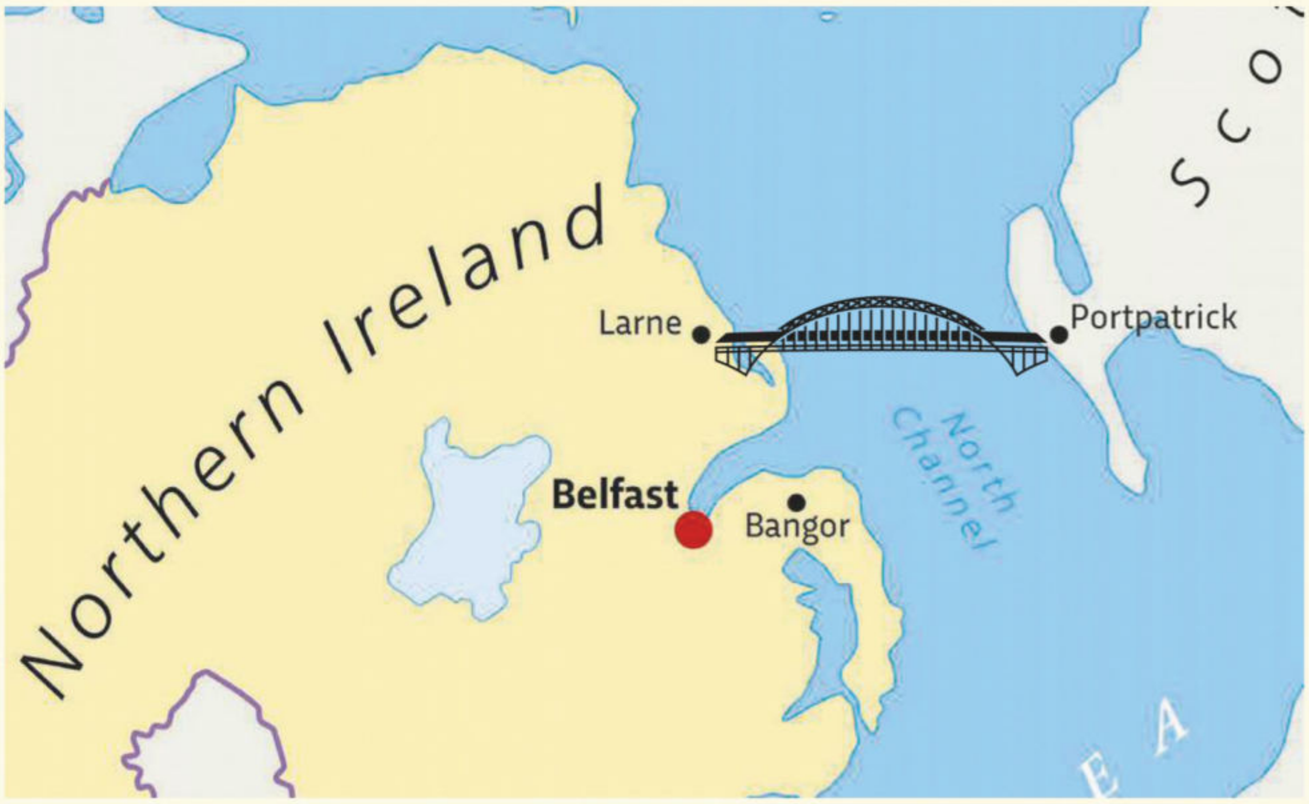
ENGINEERING

A bridge too far?

The UK government is apparently looking into the possibility of building a bridge between Scotland and Northern Ireland. But is this even possible?

Prime Minister Boris Johnson's official spokesperson raised a few eyebrows recently when they declared that a "proper piece of work" was being carried out looking into the possibility of linking Scotland to Northern Ireland via a bridge spanning the Irish Sea. At the moment, the leading candidates for the locations of the route are Portpatrick on the Scottish coast and Larne on the Northern Irish coast – a span of around 40km (25 miles).

Length aside, there are a number of other significant challenges that such an enormous project would raise. For example, there's the depth of the sea, which at times reaches 300 metres, and the large spans that would be required to let any ships pass under the bridge safely, explained Ian Firth, structural engineer and fellow at the Institution of Civil Engineers.



"Another solution might be to use floating foundations; the Norwegians are doing this already," he said. "You have a floating pontoon held below the surface of the water. You still have to get down there and drill holes in the rock down below, but you're now just tying it down with some cables. Then the buoyant platform is held below the waves – you don't want it at the surface because then you're getting wave action and tidal action. You stand your bridge structures on those buoyant platforms. That's the sort of thing that potentially could be doable."

Even so, such a structure would still leave those travelling across it at the mercy of high winds and heavy rain, even taking into account any weather-shielding measures that could be fitted. However, there may be another solution.

"There's another type of floating structure, a submerged, floating tunnel. It's not bored through the rock but sits under the water," said Firth. "You tether it down, shall we say 20 metres below the water, so that ships can go happily across the top of it, but the thing is actually floating. If you're in your car, you're driving, in effect, through a tunnel. That is a very interesting, and I think really quite potentially plausible, solution."

But it's early days and there are many factors to consider, such as the ability of the transport links either side of the crossing to cope with additional traffic, and the fact that it may be more efficient to upgrade the existing ferry infrastructure, before any kind of design work could begin.

"At the moment it is an idea and not much more than that. To begin with we'd need a pre-feasibility study which looks at what the options are so that we can actually frame the scope of a feasibility study," said Firth. "After that people like me could go away and agonise over what the options are. I believe it's possible. But 'possible' and 'affordable' are two different things. I'm not trying to put numbers to it, but it is eye-wateringly expensive, and nothing like it has been attempted before. But we're in the business of finding solutions to challenges. We civil structural engineers are good at that kind of thing."

NERVOUS FLYERS

Breathe easy, nervous flyers, it's never been safer to fly on commercial airlines, a study at MIT has found. Passenger fatalities between 2008 and 2017 fell to one in nearly eight million boardings. That's down from one in 2.7 million between 1998 and 2007, and one in 1.3 million between 1988 and 1997.

CYCLISTS

It's time to squeeze into some Lycra: cycling to work can reduce your likelihood of dying by up to 13 per cent, a study by the University of Otago in New Zealand has found. There was no reduction in mortality for those who walked or took public transport.

Good month

Bad month

CITY SLICKERS

Growing up in cities may negatively affect our sense of direction, data collected by the mobile game *Sea Hero Quest* suggests. After analysing data from almost half a million people from 38 countries, a team from the French National Centre for Scientific Research found that those who grow up in the countryside are better navigators.

WINE LOVERS

Hotter temperatures due to climate change could make up to half of wine-producing regions unsuitable for planting grapes, a study at the University of British Columbia has found. However, switching to hardier grape varieties could lessen the impact.

GETTY IMAGES X3 ILLUSTRATIONS: JOE WALDRON

WARNING

Psychedelic 'magic' mushrooms are a Class A drug according to UK law. Anyone caught in possession of such substances will face up to seven years in prison, an unlimited fine, or both. Info and support for those affected by substance abuse problems can be found at **bit.ly/drug_support**

PSYCHOLOGY

Psychedelic compound may boost wellbeing of cancer patients

A one-time, single-dose treatment of psilocybin (a compound found in psychedelic mushrooms) combined with psychotherapy appears to help with anxiety and depression in cancer patients for up to five years, according to research at NYU Grossman School of Medicine.

In a landmark study carried out in 2016, the team found that psilocybin combined with psychotherapy sessions produced immediate, substantial and sustained improvements in anxiety and depression and led to decreases in cancer-related demoralisation and hopelessness, improved spiritual wellbeing, and increased quality of life in a group of 29 cancer patients. Six months later they found that 60 per cent to 80 per cent of participants had significant reductions in depression or anxiety, sustained benefits in existential distress and quality of life, as well as improved attitudes toward death.

Now, in a follow-up study five years later, more than 70 per cent of the participants said the psilocybin-assisted therapy brought long-term positive life changes and rated it as among the most personally meaningful and spiritually significant experiences of their lives

"Adding to evidence dating back as early as the 1950s, our findings strongly suggest that psilocybin therapy is a promising means of improving the emotional, psychological and spiritual wellbeing of patients with life-threatening cancer," said lead researcher Dr Stephen Ross. "This approach has the potential to produce a paradigm shift in the psychological and existential care of patients with cancer, especially those with terminal illness."

Although the exact way psilocybin works is not fully understood, the researchers believe it can make the brain more flexible and receptive to new ideas and thought patterns. Previous research indicates that it targets a network of the brain known as the default mode network, which becomes activated when we engage in self-reflection and mind wandering, and helps to create our sense of self. In patients with anxiety and depression, this network becomes hyperactive giving rise to rumination and worry. Psilocybin appears to shift activity in this network and helps people to take a more broadened perspective on their behaviours and lives.

However, the researchers warn against any attempt to self-medicate using psilocybin, noting that it should be taken in a controlled and psychologically safe setting, preferably in conjunction with counselling from trained mental health practitioners or facilitators.

UP TO TWO-THIRDS OF ALL FOOD MAY BE WASTED AND THE RICH ARE THE WORST OFFENDERS

It's commonly believed that one-third of all food is thrown away, but this "grossly underestimates the extent of food wasted," according to researchers in the Netherlands. They found food wastage to be rising rapidly from those with a daily spend of £5.20 or more. The 'one-third' figure was first estimated in 2005 by the Food and Agriculture Organization of the United Nations (FAO), who found food waste to be 214 calories per person, per day. However, this didn't account for differences in income and buying habits. The new study estimates it to be almost double, at 527 calories a day.

In numbers

1/3

The proportion of UK doctors thought to be stressed or burnt out, according to a study published in *The British Medical Journal*.

2.23 BILLION YEARS

The age of the Yarrabubba meteorite crater in Western Australia, as estimated by a team at Curtin University.

7 YEARS

The length of time an olm, a small cave-dwelling salamander, stayed motionless in Bosnia-Herzegovina, as found by Eötvös Loránd University.

MARINE BIOLOGY

Cuttlefish skimp on lunch if shrimp is for dinner

When cuttlefish know that their favourite food will be on the menu at dinnertime, they'll eat less for lunch, according to new research carried out at the University of Cambridge.

Cuttlefish are a type of cephalopod mollusc and they have a wide diet that includes crab, fish, squid and shrimp, but they show definite preferences for particular foods. After establishing that shrimp was the favourite food of European common cuttlefish (*Sepia officinalis*), the researchers found that when they reliably gave the cuttlefish a meal of shrimp in the evening, they'd eat fewer crabs when they were offered during the day. When the shrimp dinners were only provided at random, the cuttlefish would eat more crabs during the day as they could not predict if their favourite food would be available later on.

> "This could offer new insight into when complex cognitive ability evolved"

"It was surprising to see how quickly the cuttlefish adapted their eating behaviour – in only a few days they learned whether there was likely to be shrimp in the evening or not. This is a very complex behaviour and is only possible because they have a sophisticated brain," said Pauline Billard, who took part in the research.

When cuttlefish hatch out, they already have a large central nervous system and are able to learn from a young age. They are capable of responding to their environment in a flexible fashion, and can adapt their hunting, mating and behaviour strategies to ensure the best possible outcomes. In this study, they proved that they could adjust their foraging behaviour on a day to day basis to guarantee that they were eating enough, but also not missing out on their favourite foods.

In evolutionary terms, cephalopods split from the vertebrate lineage around 550 million years ago, yet their nervous systems are remarkably similar. These findings could offer new insight into when complex cognitive ability evolved.

Cuttlefish will skimp on lunch if they know their favourite meal, shrimp, is for dinner

Fish remains from the Takarkori rock shelter

ANTHROPOLOGY

Humans living in the Sahara Desert 10,000 years ago ate fish for supper

During the Holocene, the Tadrart Acacus mountains in the Sahara Desert were humid with many permanent water bodies

ALAMY, GETTY IMAGES, SAVINO DI LERNIA

An investigation into the animal remains in the Sahara Desert has revealed that humans living there 10,000 years ago were eating fish for their supper. Researchers from the Natural History Museum in Belgium and the Sapienza University of Rome excavated a total of 17,551 bones, including those of fish, toads or frogs, crocodiles and birds.

Archaeologists have previously found evidence that for much of the early Holocene (around 10,200 to 8,000 years ago) the Tadrart Acacus mountains in the Saharan Desert were more humid than they are today. “It is hard to say how much water was there,” said Prof Savino di Lernia, the lead author of the study along with Prof Wim Van Neer. “During the early Holocene there were permanent water bodies with plenty of fish, but things changed around 5,900 years ago, with the onset of present desert conditions.”

Humans were known to have settled in the region during the early Holocene, as archaeologists have found stone structures and fireplaces in the area. The team focused on excavating parts of the Takarkori rock shelter, one of many shelters in the Tadrart Acacus mountains, to identify and date animal remains there. Almost 80 per cent of the remains found were fish, two-thirds of which were members of the *Clariidae* genus of catfish. The others were of the genus *Tilapia*. The study found that the consumption of fish decreased over time, as the humans started to concentrate on hunting and livestock. Yet the catfish decline was less significant than *Tilapia*, as the catfish can live in warm, shallow waters.

According to the authors, this study reveals crucial information about the dramatic climate changes that led to the formation of the largest hot desert in the world. “Takarkori rock shelter has once again proved to be a real treasure for African archaeology and beyond: a fundamental place to reconstruct the complex dynamics between ancient human groups and their environment in a changing climate,” they said.

Data crunch

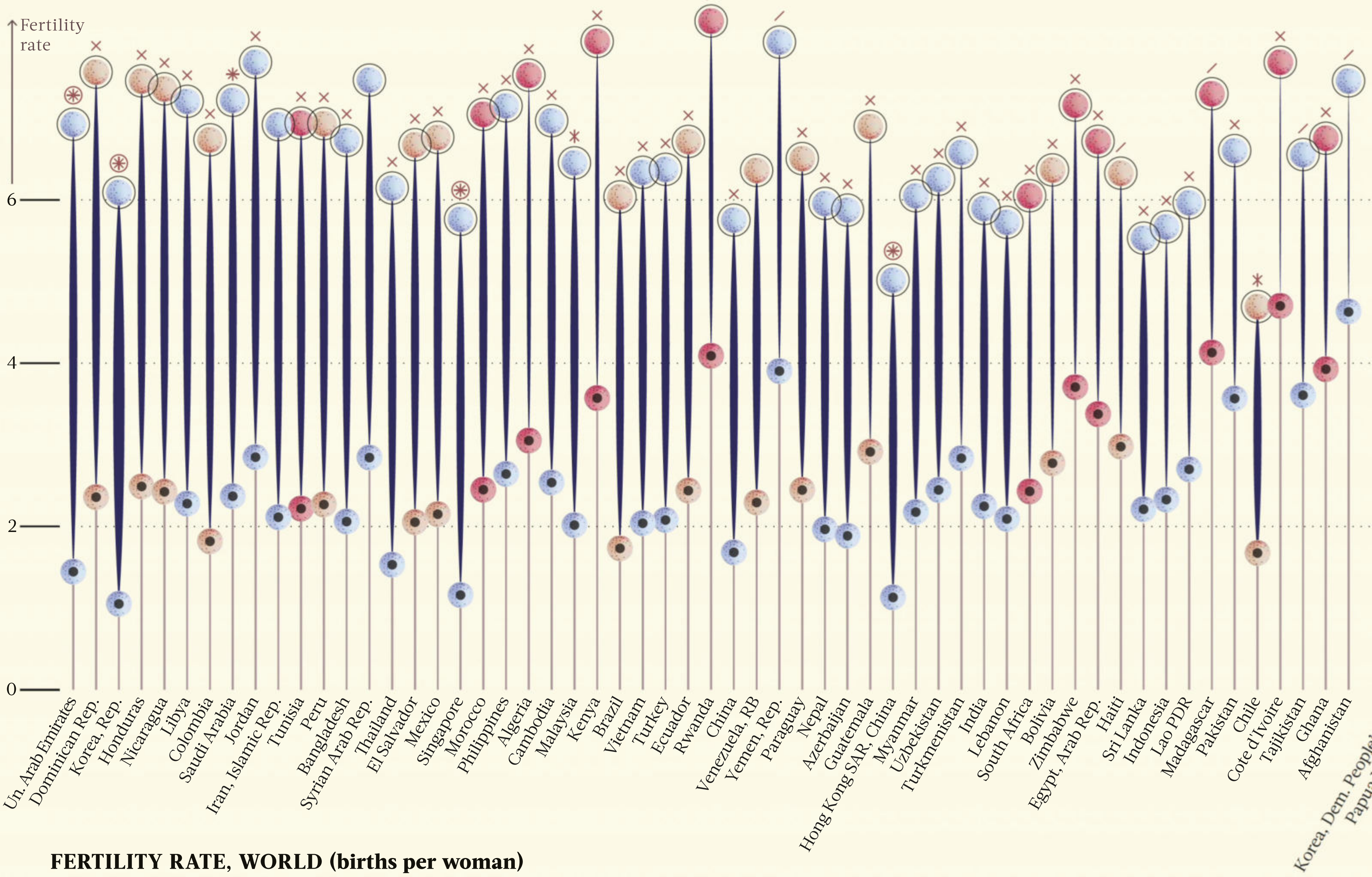
BABY SLUMP

INFOGRAPHIC BY FEDERICA FRANGIPANE

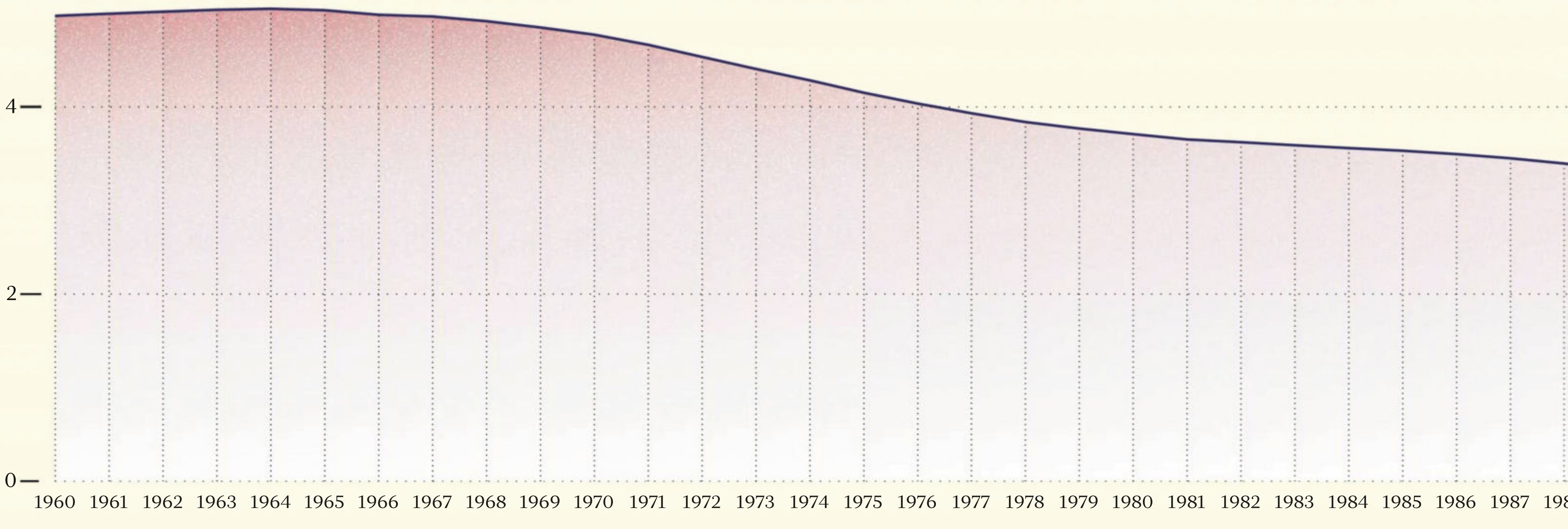
SOURCE: GLOBAL FOOTPRINT NETWORK, 2019 NATIONAL FOOTPRINT ACCOUNTS

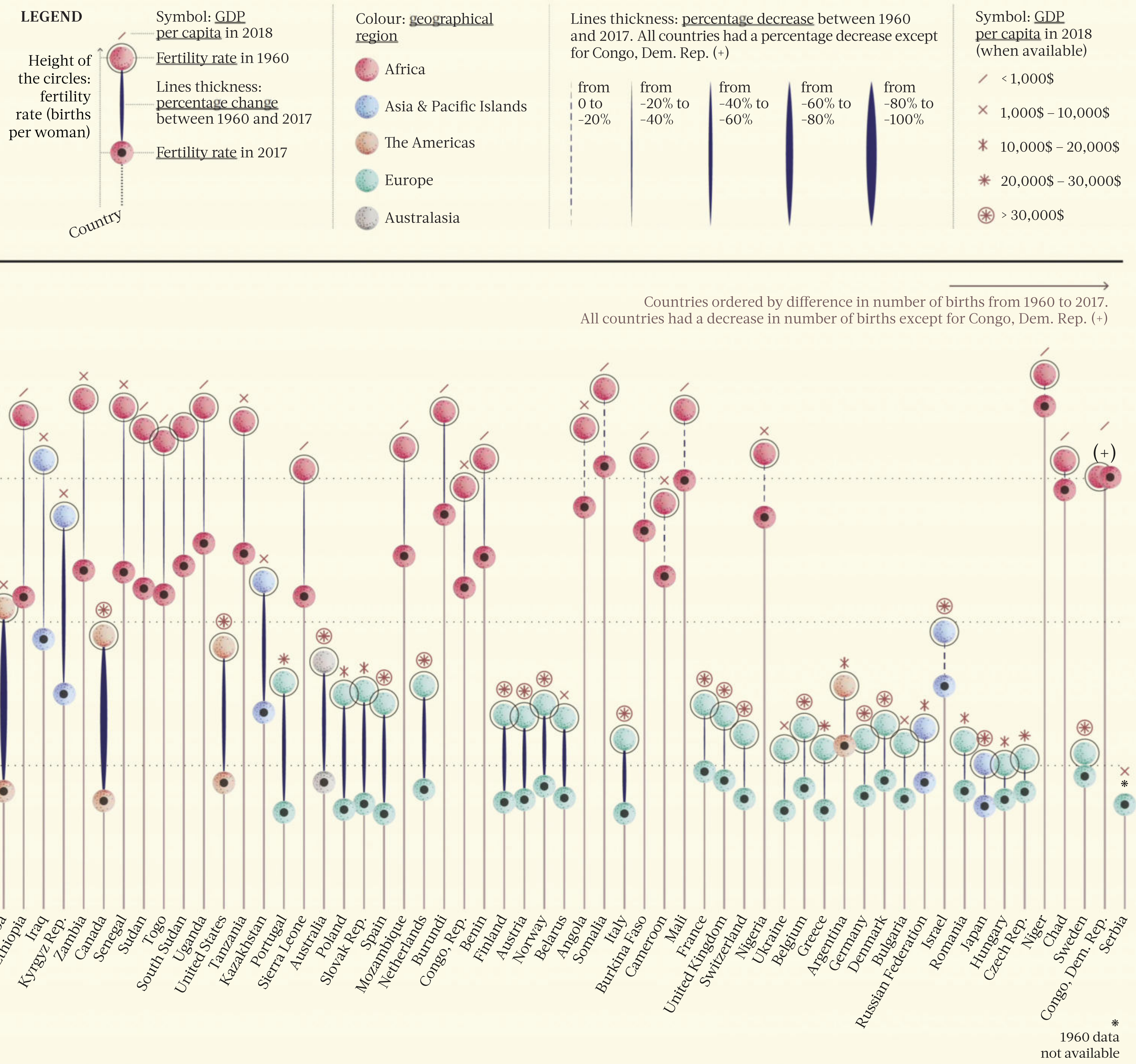
Between 1960 and 2017, fertility rates dropped dramatically around the world, with the global average falling from around five births per woman, to under 2.5. Fertility rates are generally higher in the countries with lower GDP. This is due to a number of factors, including lack of access to contraceptives, lower levels of female education, and a desire to have children for labour. As populations gain greater access to contraception, and more women enter education and work, fertility rates drop. Another key reason for the drop is that child mortality rates are also falling, which means that women are setting out to have fewer babies.

FERTILITY RATE BY COUNTRY (births per woman)



FERTILITY RATE, WORLD (births per woman)





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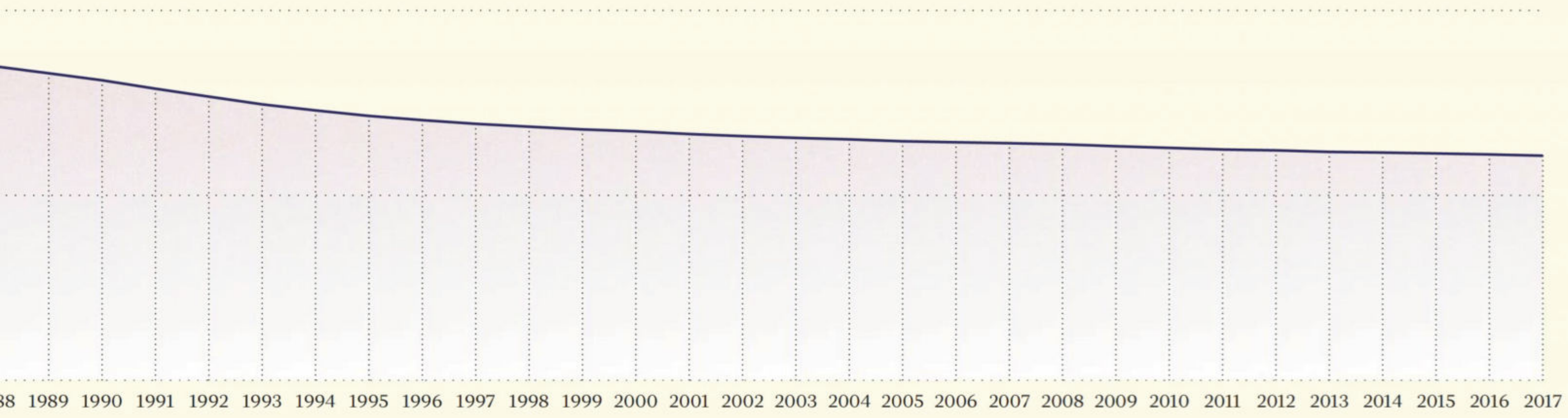


GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**

Initiatives to plant trees are popular, but could they also be problematic?

CITIZENS ASSEMBLE

The UK's new 'citizens' assembly' on climate change met for the first time in January in their first chance to quiz experts on how climate policy and science will affect the UK.

The 110 ordinary people from across the country were specifically chosen to represent diversity of age, region and opinion on climate change. Questions they asked included: 'Which is better for the environment – British beef or avocado from Peru?' and 'How committed are other countries to achieving net zero?'. The assembly will be tasked with delivering a report to Parliament in April 2020 on how the country should tackle the climate crisis.

CLIMATE

Planting a trillion trees may not be a good idea

Maintaining current ecosystems may do more to capture carbon than planting trees in unsuitable landscapes

A new global initiative to 'grow, restore and conserve' one trillion trees around the world was launched last month by the World Economic Forum.

The '1t.org' plan, backed at Davos by US President Donald Trump and primatologist Jane Goodall, aims to begin a "mass-scale nature restoration" to protect biodiversity and fight climate change.

"We are facing a planetary climate crisis and trees are one of the most effective ways to sequester carbon and stop the worst effects of climate change," said Marc Benioff, chief executive of the software company Salesforce, which is funding the initiative, in a statement.

Critics, however, have been quick to point out caveats to the new initiative. They warn that tree planting as a major absorber of carbon has been

FARMLAND HAS A KEY ROLE TO PLAY IN TACKLING CLIMATE CHANGE

A fifth of all the UK's farmland needs to be used to tackle climate change by 2050, according to government climate advisors.

The UK's forestry cover needs to expand from 13% to at least 17%, the Committee on Climate Change (CCC) said, while the public will need to cut beef, lamb and dairy consumption by 20%.

"The options we're proposing would see farmers and land managers delivering actions to reduce emissions," said Lord Deben, chairman of the committee.

The changes in land use would need funding of £1.4bn per year, but could produce a net social benefits of £3.3bn a year, the committee said.

exaggerated and could distract from other important policies.

The initiative references a widely reported study by Swiss researchers published last year in the journal *Science*, that claimed planting a trillion trees could capture a third of all the carbon released by humans since the Industrial Revolution. However, a team of 46 scientists carried out a strong critique that was published in the same scientific journal shortly after.

They argued the study had vastly overestimated the amount of carbon which could be stored by growing trees, and failed to assess the impacts on people and ecosystems where these trees would be planted.

> **"The study vastly overestimated the amount of carbon which could be stored by growing trees, and failed to assess the impacts on ecosystems"**

LOCATION, LOCATION, LOCATION

"A trillion trees is potentially a really bad idea, because of the ways that we must think about the implementation," said Dr Joseph Veldman, assistant professor of ecology at the Texas A&M University and lead author of the critique. Choosing the right location is important. "Many of the places that are already deforested are not available to be turned back into forest," he said, which means that trees may be planted in other types of less suitable landscapes.

"We know that maintaining current intact forests, savannahs and grasslands – existing ecosystems that don't need to be restored – would be a better bet for carbon, rather than let them be destroyed and then have to plant some new trees," he explained.

Last year's report on land use by the International Panel on Climate Change (IPCC) also warned that widespread tree planting, also known as 'afforestation', could come with risks. For example, it could increase competition for land and threaten food security by raising food prices.

However, the IPCC concluded that at least some afforestation is likely to be needed in order to limit global warming to 1.5°C above pre-industrial levels.

INSPIRED

EAGER BEAVERS

The National Trust has released a pair of adult beavers on Exmoor in an effort to improve biodiversity and tackle flooding and drought.

WOOD IS GOOD

Building new buildings with timber, rather than other materials, offers the chance to store carbon on a vast scale, according to a new study carried out at Yale School of Forestry and Environmental Studies.

EXPIRED

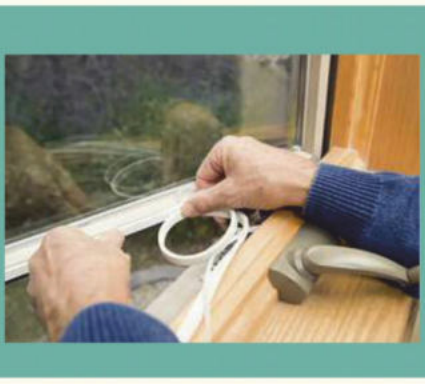
TIME TO JUMP SHIP

Powering ships with liquid natural gas (LNG) rather than conventional fuels does not benefit the climate, a report from the International Council on Clean Transportation has found. This is because LNG is mostly methane, which is a powerful greenhouse gas.

NO DAM GOOD

Planned hydropower dams around the world could greatly increase threats to many freshwater fish species by breaking up their habitats, a study from Radboud University in the Netherlands has found.

IT'S EASY BEING GREEN



INSULATE YOUR HOME

The energy used by most people in their homes still comes from fossil fuels, leading to around 20 per cent of the UK's greenhouse gas emissions. But people can take steps to reduce their energy use – and bills – according to the Energy Saving Trust. Homeowners can insulate roofs and walls, and use double glazing in good condition. Simply draught-proofing doors and windows can stop homes from losing heat, and is something many people can do themselves. However, make sure not to block any intentional ventilation, such as extractor fans, so that air can still flow through the building.

GETTY IMAGES X4, PRESS ASSOCIATION, WIKI COMMONS, BJOERTVEDT/FLICKR

Dr Stuart Clark astronomer and cosmologist

Horizons

The Voyager mission and the Pale Blue Dot: How the most famous picture in science came to be

One of Voyager's founding scientists Garry Hunt tells astronomer Stuart Clark about the idea behind the image, how it shaped his life and how NASA has changed since the photo was created 30 years ago.

They call it the Pale Blue Dot. It is simultaneously one of the least striking photos you are ever likely to see, yet at the same time, probably the most significant. The only thing of real importance in the image is one single pale blue pixel. Yet the light captured in that pixel is coming from Earth. It's what our entire planet looks like from a distance of around six billion kilometres (four billion miles). It inspired the famous planetary scientist Carl Sagan to write his 1994 book, *Pale Blue Dot: A Vision Of The Human Future In Space*. In it, he wrote, "Look again at that dot. That's here. That's home. That's us."

It was a realisation that even the team who masterminded the picture were not fully prepared for until they saw the image. "We all realised that what this actually shows is that the Earth is no more than a tiny speck among the stars. It was a very chilling picture," says Garry Hunt, a founding member of Voyager's imaging team. He uses the word 'chilling' advisedly because he says it really made him recognise just how fragile the Earth is. "It really brought it home to us that you cannot go and live on Mars, you can't go and live on Titan, you can't go and live on Enceladus. There is nowhere else we can go," he says.

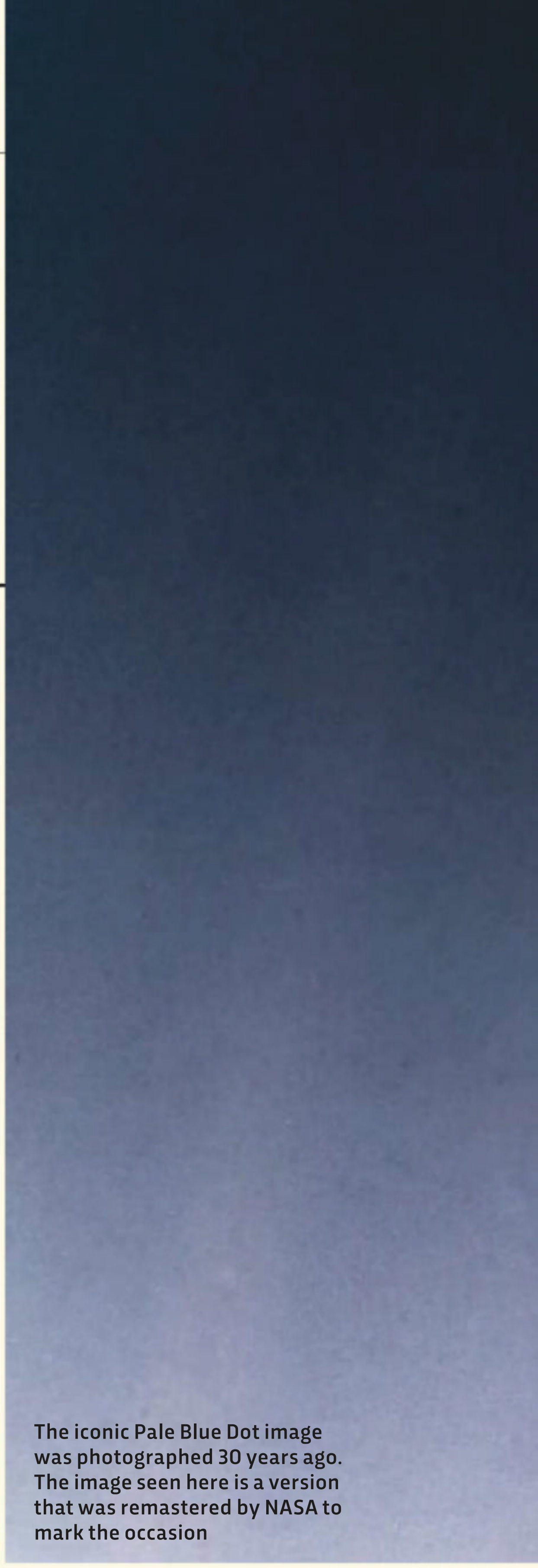
Hunt became involved in the Voyager mission when he was working at NASA's Jet Propulsion Laboratory in California as an atmospheric physicist. He saw the mission as an opportunity to study the atmospheres of other planets and relate them to Earth. It set him on a career path he has been travelling ever since.

"For many decades, I have been talking to audiences in schools, universities, and businesses – you name it – I'll talk to anybody about climate change. And the first picture I always show is this picture of the Earth as a blue dot."

SNAPPING THE SOLAR SYSTEM

In 1990, Voyager 1 had already encountered Jupiter, Saturn and Titan, and was heading into deep space. The imaging team continued working together for Voyager 2's encounter of Uranus and Neptune, but they chose Voyager 1 to take the picture on 14 February because it had the best vantage point to snap the photo. The Pale Blue Dot was just 1 of 60 images taken that day that were designed to capture the planets of the Solar System (Mercury and Pluto could not be imaged).

"The mission was essentially over by that time and we wanted to finish with something really special," says Hunt. "The planets were all in perfect alignment and we thought if we could take the family portrait of all the planets it would be wonderful. The imaging team



The iconic Pale Blue Dot image was photographed 30 years ago. The image seen here is a version that was remastered by NASA to mark the occasion

NASA/JPL

> "We all realised that what this actually shows is that the Earth is no more than a tiny speck among the stars"

said, this is our last thing, then we will turn the camera off."

And NASA agreed but the team had to wait for the results. Although the image was taken in February, it could not be downloaded immediately because NASA's Magellan and Galileo spacecraft were using all the bandwidth of the NASA Deep Space Network. Only in March could the images begin to be downloaded. In total, there were 640,000 pixels of data to be downloaded. That might not be much by modern image standards but when the spacecraft is six billion kilometres away and the antenna only has a few hundred watts of power, it takes a long time. By May, all the images were received, processed and made public.

The twin Voyager spacecraft left an enormous scientific legacy. They discovered the volcanoes on Jupiter's moon Io, and the underground ocean on Europa. They gave us our first close-up look at Saturn's rings and the complex way they behave.

Looking to the future, Hunt thinks that one destination is crying out for a return visit. "Oh I'd go for Titan without question," he says. This is because Titan is thought to be similar to Earth before life began. The Voyager team analysed Titan's thick atmosphere in 1980, then the European Space Agency's Huygens lander touched down on its surface in 2005. But Hunt thinks there is much more to do because of what it could tell us about the primordial Earth. "There is no question that we've got to have a jolly good look at Titan," he says.

GOLDEN OPPORTUNITY

Hunt recognises that his stint on the Voyager project happened at a golden time. Space exploration was in its infancy, and there was a tremendous pioneering spirit that pervaded the endeavour at that stage. Now, he says, NASA is different. "It's much tougher now because money is tight. It was tough in my day, but it's very much tougher now. The joy of JPL was the ability to experiment, to try, to learn, to make mistakes. That's more difficult now."

And it is more than just money that is invested in these missions: it can be people's entire careers. "I gave my first interview to the BBC about Voyager 48 years ago, and here I am this morning doing another interview about Voyager. When you go and watch a spacecraft launch, just imagine if it failed on the pad or some other aspect went wrong. People's careers are destroyed."

Luckily that did not happen for Voyager, and in the three decades since the Pale Blue Dot was first released, its significance has only grown.

"I have been battling climate change since my research days in the late 60s and early 70s. In the 90s I was involved in the debate with businesses over whether climate change was important. And I lost. And I was horrified that I lost. But now, people are suddenly realising what is actually happening," says Hunt. "The whole planet has got to work together and the Voyager picture is almost the badge that we should be looking at. It is certainly the Valentine's Day card that Voyager is giving to everyone, and saying, 'This is where you are, take note. You are a very frail fragment amongst all the stars.'"

by **DR STUART CLARK**

Stuart is an astronomer, cosmologist and science writer. His new book, Beneath The Night *(£14.99, Faber), comes out in October this year.*

Wuhan, Hubei province, China

CORONAVIRUS

New hospitals spring up in Wuhan

With existing hospitals reporting bed shortages due to the demand created by the rapid spread of coronavirus, on 24 January China decided to begin constructing new ones. Less than two weeks later, the doors of the new medical facilities opened to the first patients

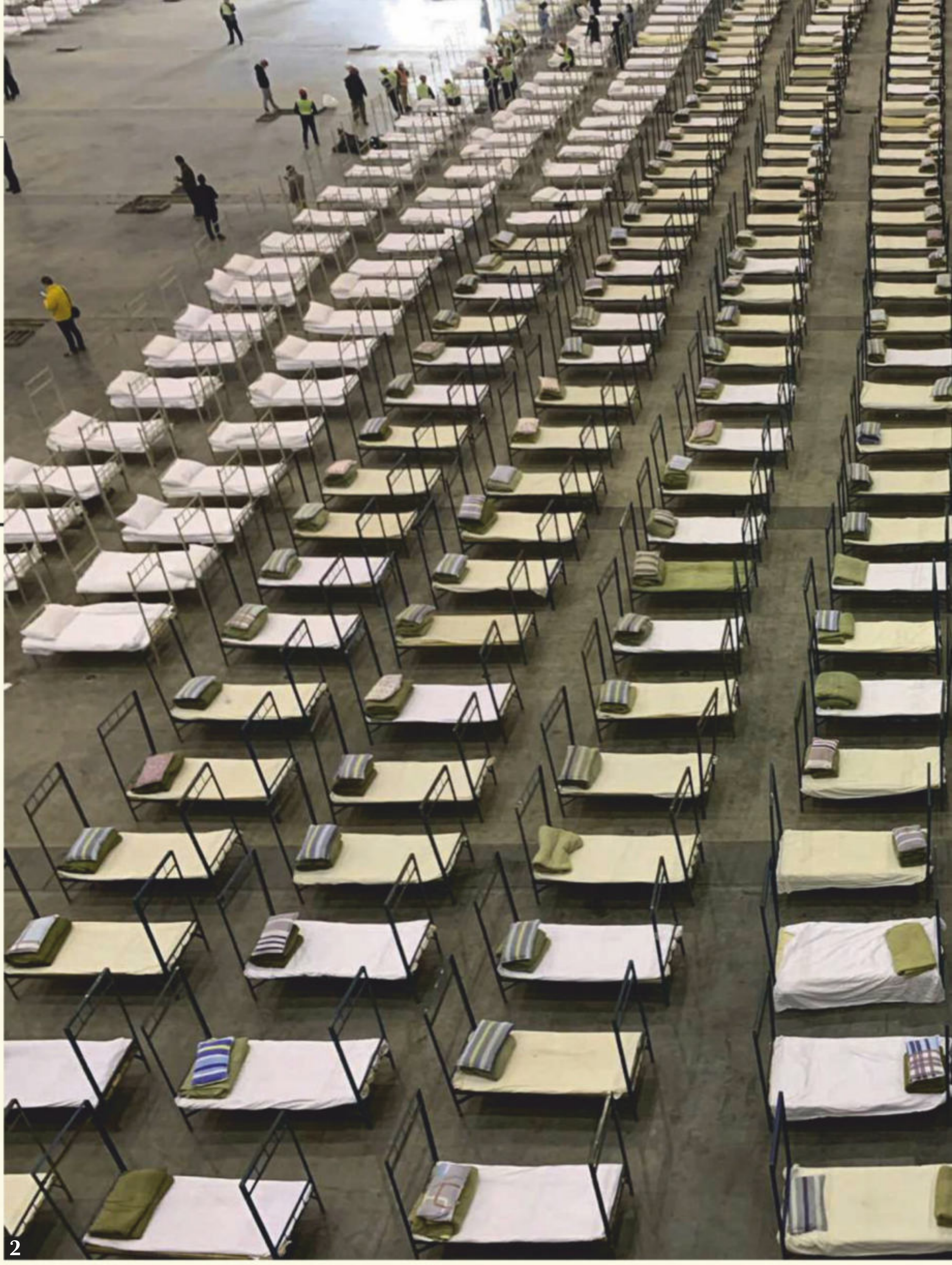
1. Two new hospitals sprung up in Wuhan, the capital city of Hubei province, in the first week of February. It had taken less than two weeks to go from breaking ground on the site to admitting the first patients. The two new hospitals – the 1,000-bed Huoshenshan (pictured) and 1,600-bed Leishenshan – are based on the design of Beijing's Xiaotangshan hospital, which was built to cope with 2003's SARS outbreak. Huoshenshan and Leishenshan were made from prefabricated units to get them built quickly.

2. Three 'field' hospitals were also being set up in Wuhan in early February. The pictured 2,000-bed facility was in a building that, until the coronavirus outbreak, had been an exhibition centre. Another of the city's exhibition centres and a gym have also been commandeered to handle the volume of patients.

3. Patients began arriving at Huoshenshan on Tuesday 4 February. Two days later, the first patients were expected to be admitted to Leishenshan hospital.

4. 1,400 medical staff had been drafted in from China's military to treat patients at the Huoshenshan hospital.

5. Efforts to control the spread of coronavirus in areas outside Hubei see volunteers disinfecting public areas. Here, a railway station in Hunan, a province to the south of Hubei, is sprayed with chemicals to kill the virus.



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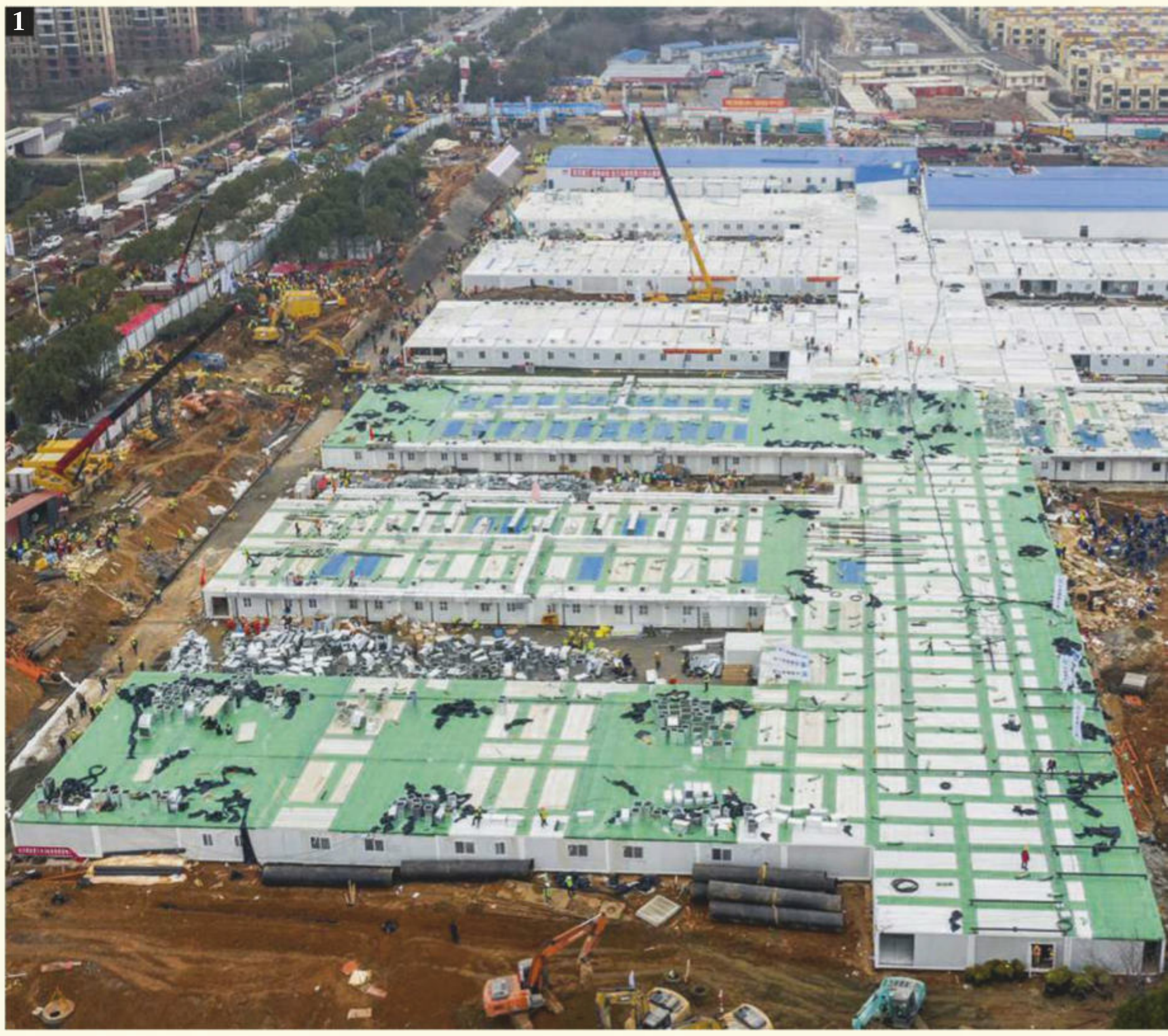

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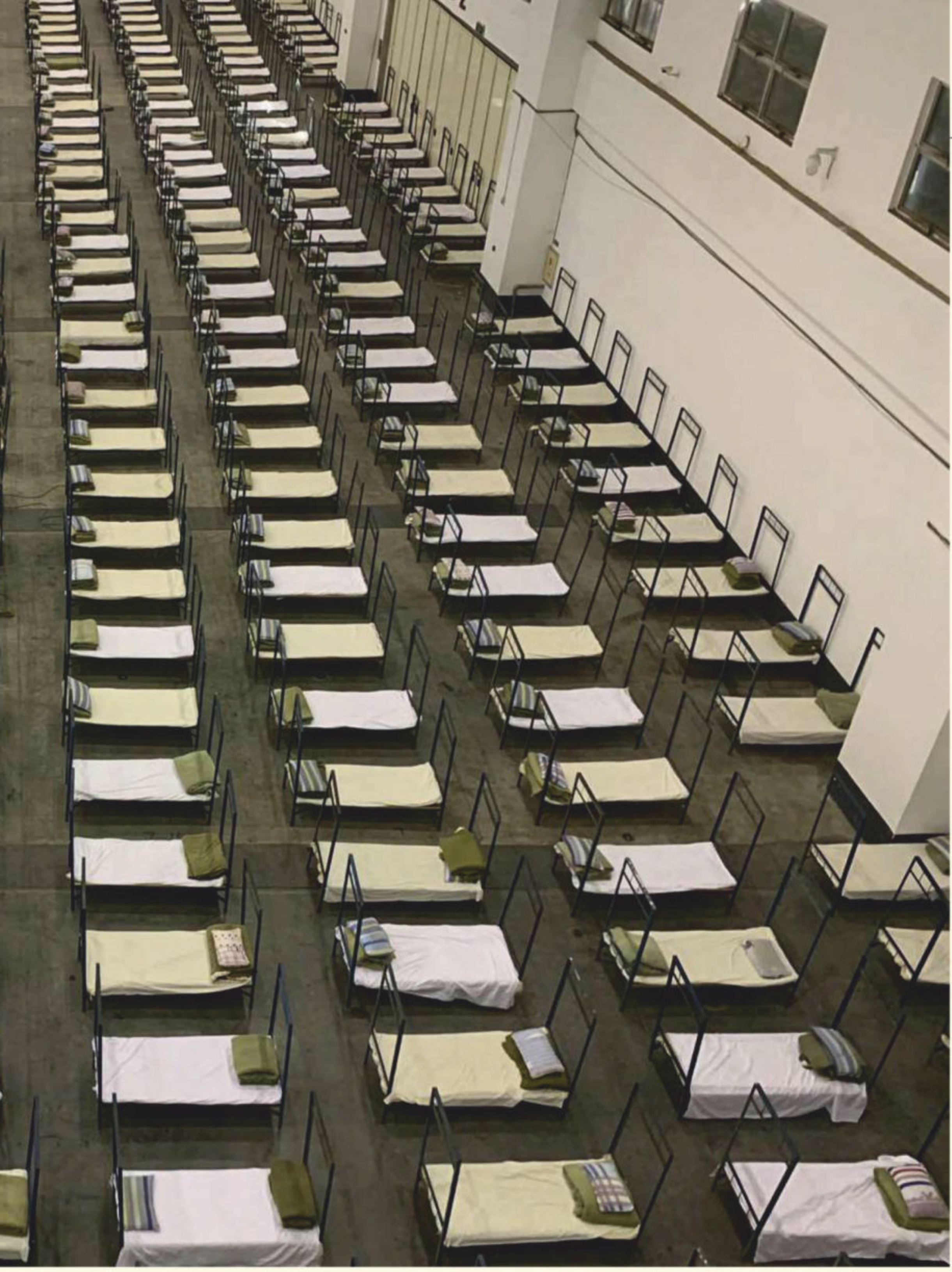

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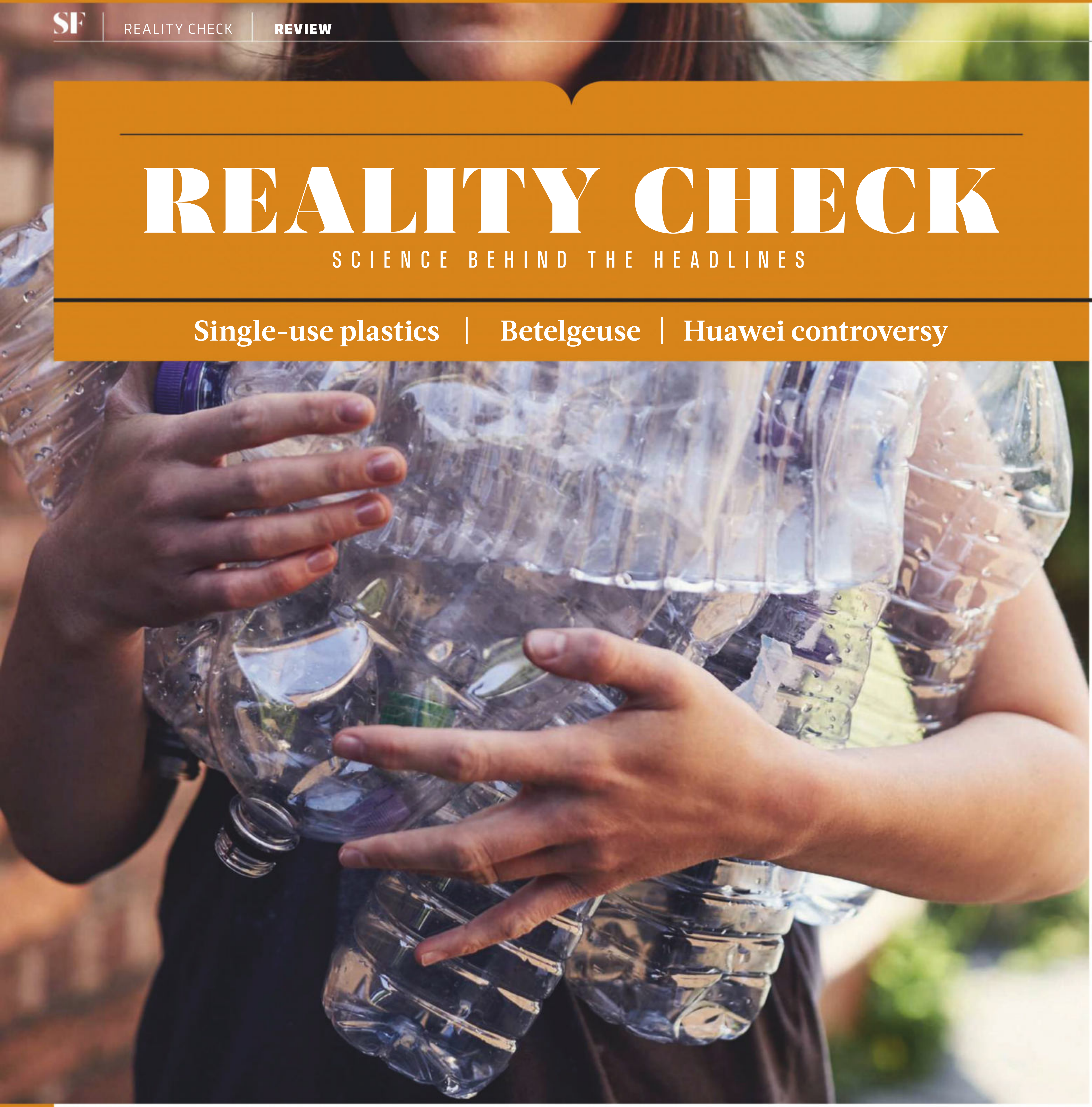
Single-use plastics | Betelgeuse | Huawei controversy



REVIEW

SINGLE-USE PLASTIC: ARE BIODEGRADABLE ALTERNATIVES WORSE FOR THE ENVIRONMENT?

Retailers are under pressure to move away from single-use plastic. But could a knee-jerk reaction actually make things worse?

> **“Most biodegradable polymers will only biodegrade at temperatures of 50°C or 60°C, in the particular conditions of an industrial composter”**

BBC *Visit the BBC’s Reality Check website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

PLASTICS WATCH

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ABOVE This recycled plastic in a factory can have a new lease of life over and over again. Mark Miodownik says that more effort should be made to ensure all plastics are recyclable, rather than creating compostable versions

Retailers are beginning to switch from single-use plastic to biodegradable, compostable or recyclable alternatives, according to research by environmental think tank Green Alliance. But could these quick fixes cause further harm to the environment? We talk to **Mark Miodownik**, a materials scientist who’s leading the Big Compost Experiment. This nationwide citizen science experiment will explore whether home-compostable plastics really do compost in your garden.

HOW DO YOU MAKE BIODEGRADABLE PLASTICS?

Plastics are made of long-chain carbon molecules, and so polythene, for instance, is lots of little ethylene molecules linked up, and they create this sort of plastic bag material which is strong, tough and light.

It turns out that most of life also involves long-chain carbon molecules, so you can get these structures from things like corn and starch and so, you basically harvest a crop, use that as your carbon source, and create polymers based on those. These polymers work the same as the ones we derive from petrochemicals.

But you can go one stage further and you can make them sort of tasty to microorganisms, so little bacteria will eat them, and then this is where biodegradable plastics come from.

HOW SHOULD WE DISPOSE OF BIODEGRADABLE AND COMPOSTABLE PLASTIC?

There’s a slight problem with it at the moment. In order to get the properties that we need from plastics, for them to last six months or a year protecting your food, you want it to last a long time without it being eaten by bugs. Otherwise, food would go off in your cupboard.

And you’ve got to remember, these plastics need to survive humid and hot environments. And so, in order to get the plastics to be as good as that, you often have to do things chemically to them. That makes them less easy for bugs to eat, and that means that their biodegradability requires certain conditions.

So, most biodegradable polymers will only biodegrade at temperatures of 50°C or 60°C, for instance, in the particular conditions of an industrial composter. You might get something like a biodegradable wipe, and it says biodegradable on it, but unless you put that thing in an industrial composter at the right temperature and the right humidity with the right bugs, it will not biodegrade. It will still be in the environment a year later; if you put it in the sea, it will be there for years. So, you really should put it in the general waste bin.

WHAT’S BETTER: BIODEGRADING OR RECYCLING?

If you have a recyclable plastic, then you know where to put it: you put it in the recycling. We have systems in place. And the good thing here is that you’re hanging on to the carbon. But in the case of a biodegradable plastic, having got it from a crop, if you just biodegrade it in an industrial composter then potentially you’re putting the carbon back in the atmosphere. What we really want to do is keep carbon in the system, because we as we know, we’re trying to get rid of carbon dioxide out of the atmosphere. We want everything to be recyclable, and we want to recycle it.

IS THERE ANY VALUE IN SWAPPING SINGLE-USE PLASTIC FOR THESE ‘BIODEGRADABLE’ MATERIALS THAT DON’T BIODEGRADE AND CAN’T BE RECYCLED?

I think there isn’t any value at the moment, because there isn’t any such thing as a sustainable material. Paper’s not sustainable, steel is not sustainable, glass is not sustainable. Things are not sustainable in their own right. Only a ►

GETTY IMAGES X2

system can be sustainable. And what I mean by a system is: someone manufactures something out of steel, you use it on your car or your razor, you then dispose of it, it gets recycled, and then it goes back into the system. That's a system that can be sustainable if you make sure that you're using the energy properly.

If you then try and do biodegradables, what you're trying to do is create a system in which the CO_2 plays a part, and it seems to me that we're already problematically dealing with CO_2 in the atmosphere, so this is a difficult system to become sustainable in my view.

IS IT WORTHWHILE SWAPPING SINGLE-USE PLASTIC FOR A DIFFERENT SINGLE-USE MATERIAL?

There is a system for paper recycling, but if it's contaminated with food, it won't be recycled. And actually, paper uses more energy and water in general than plastics. So, you're potentially making the water issues worse and climate change worse by swapping one single-use material for another.

So, the truth is that I think that people are so alarmed with plastic and disgusted about the pollution, and they're right to be disgusted, but what we don't want are these knee-jerk reactions which are really a greenwash. They're sort of placating you, but I think the inherent way to do something about the problem is to change the system.

WHAT'S THE WAY FORWARD?

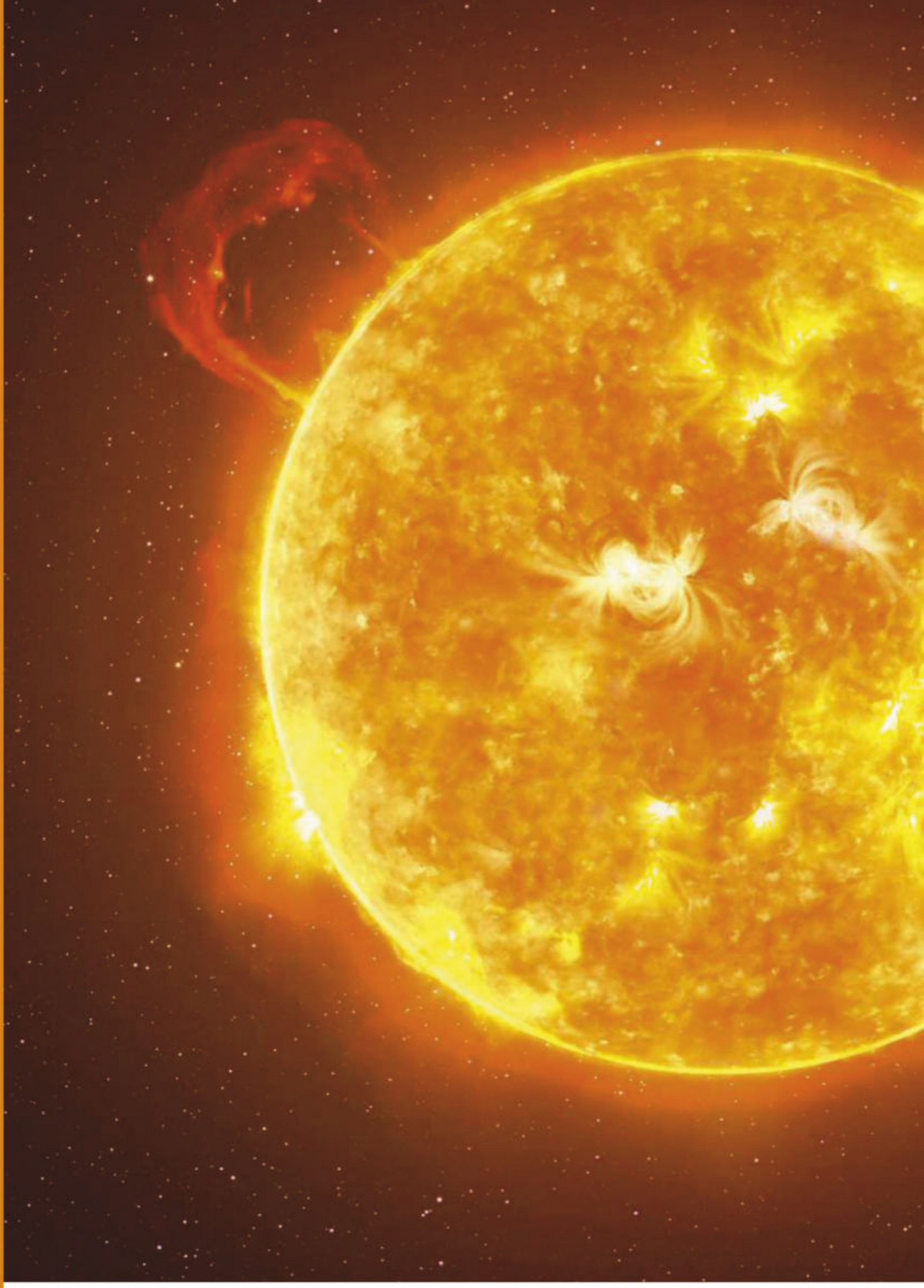
We're not going to lose plastic from our lives, because it's useful. It reduces food waste, it reduces waste of almost everything, and it's lightweight and tough for transporting goods across the planet and all of that helps reduce CO_2 emissions. In our clothes, now, the average piece of clothing is 67 per cent plastic. Our shoes are mostly plastic. Lots of stuff in our lives is all coated with plastic. It's all vital, but we don't have any systems for recycling those yet and I think we really, seriously fast need to redesign everything, so that there are systems for recycling everything in our lives.

We need to make sure every single plastic in a supermarket is recyclable, and it all goes into one bin and you don't have to make any head-scratching decisions. And those plastics all get recycled back into new plastics which then get used for more packaging. That is the future.

with **DR MARK MIODOWNIK**

Mark is professor of materials and society at UCL.

interviewed by BBC Science Focus *online assistant Sara Rigby.*



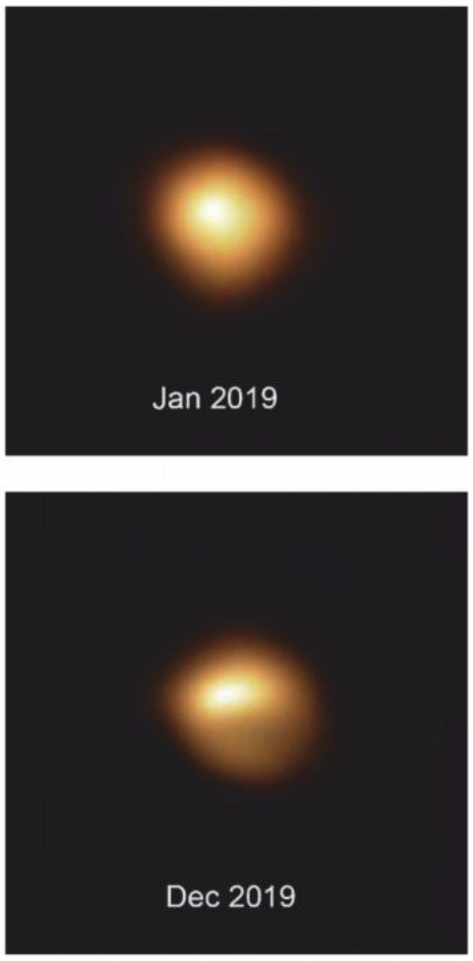
ANALYSIS

BETELGEUSE: IS THIS SUPERGIANT ABOUT TO EXPLODE?

The star has been behaving strangely in recent months. Is it about to go supernova?

In the constellation of Orion, something strange is afoot. In October last year, the red star Betelgeuse – which marks Orion's right shoulder (or left as we look at it) – began to get unusually dim. During January and February 2020, it reached a record low – around 40 per cent of its usual brightness. We know Betelgeuse is a mature star, and it will one day explode in a supernova. But this dimming has led to speculation that a supernova could be imminent. Might this be a moment of calm before the star expires in a cosmic death-blast?

The dimming of Betelgeuse is not unexpected. (The name of the star has its origins in Arabic, and there's no consensus on how to pronounce the Westernised version. However,



BBC FOUR

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'Beetlejuice' is a common variant.) It's a 'variable' star, whose brightness fluctuates. Betelgeuse's fluctuation follows a roughly 420-day cycle, and – in line with this cycle – there are signs that the star is slowly brightening again as of mid-February.

"But even if Betelgeuse perks up, it still leaves us with questions," says Dr Emily Levesque, an astronomer who studies massive stars at the University of Washington. "It's got so much dimmer than normal – way more than we would expect."

Betelgeuse is a red supergiant – the largest class of stars in the Universe in terms of volume. It has a radius of around 600 million kilometres: if you plonked Betelgeuse in the middle of the Solar System – where the Sun is – it would reach almost to Jupiter, engulfing Mercury, Venus, Earth and Mars.

Red supergiants form when a massive star runs out of hydrogen in its core and can no longer convert hydrogen into helium via nuclear fusion. At this point, the core begins to contract, which raises the star's internal temperature and ignites a shell of hydrogen fusion around the core, causing the star's outer layers to expand and cool.

The temperature inside Betelgeuse's core is so hot that the helium there has begun to fuse into carbon. Once the helium is exhausted, the core will work its way through heavier elements, all the way to iron. At this point, the star can generate no more energy, so the core will collapse. The outer layers will follow, bouncing off the core and exploding in a supernova.

So could the dimming be a sign of an imminent supernova? Levesque admits that we still know very little about what a star will do in the final days and weeks before it explodes. But she says that the best guess for when Betelgeuse will die, is in 100,000 years. "A supernova tomorrow is not flat out impossible," she says, "But it's unlikely."

So what's responsible for the recent dimming? Betelgeuse's usual 420-day pulsation cycle – which is caused by variations in the star's size – cannot alone account for the dimming, says Levesque, so there's probably at least one other mechanism going on. One possibility is that the star is being obscured, making it appear dimmer. "We know that stars like Betelgeuse periodically shed mass from their surface, which condenses into dust around the star. This would effectively block our view," she says. "We also know that red supergiants have big convective zones on their surfaces." This is where hot gas from deep inside the star rises to the surface, where it cools and sinks again. Changes in this circulation could be altering the star's surface temperature, and hence its brightness – another possible explanation for what's going on.

Whatever Betelgeuse is currently doing, there's no question that it'll explode at some point. "It'll be absolutely unmissable," says Levesque. "The star is only a few hundred light-years away, so the light from the supernova will be incredibly bright – comparable to Venus or the Moon."

We'll see it in the sky as a pinprick of light – even during daytime – and our telescopes will be able to see the nebulous 'supernova remnant' in all its glory. But don't worry: although Betelgeuse is close to us, it's still far enough away that there'll be no danger from the supernova's high-energy radiation. As for Betelgeuse, it'll most likely become an ultra-dense neutron star.

In the meantime, astronomers are getting all the data they can. "As we study more of these red supergiants, we should get better at pinpointing what stage of their evolution they're in, and when they're likely to die," says Levesque. "We know that stars like this make most of the elements in the Universe – both when they're alive and when they die as supernovae. Understanding how this works will tell us more about how the make-up of the Universe evolved. These stars seeded the chemistry that made life possible."

ABOVE LEFT Artist's impression of the Betelgeuse star

ABOVE These pictures of Betelgeuse were taken by the Very Large Telescope. You can see that the star was dimmer and a different shape in December 2019 compared to January that year

by JAMES LLOYD

James is staff writer at BBC Science Focus.

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COMMENT

5G AND THE HUAWEI CONTROVERSY: WHY IS IT ABOUT MORE THAN JUST SECURITY?

In January, the UK government announced that Chinese company Huawei would be allowed to provide equipment to help build the UK's 5G network. In response, the US threatened to downgrade the UK's access to its intelligence and warned of additional difficulties for trade negotiations. Cyber security expert Arthur Laudrain unpicks the issues

Between the Internet of Things and smart cities, by 2030 we expect half a trillion objects to be connected to the internet, from streetlamps to autonomous cars, factories and clothes. The overwhelming majority will rely on 5G and its successor, making wireless technology essential to our daily life, our security and economy. British internet providers are already upgrading their networks alongside existing 4G hardware. On the consumer side, the first 5G-capable smartphones hit the market last year, and the UK has allowed Huawei to help build 'non-core' parts of the 5G network. This has been met with concern, because China seems to be building a surveillance state that is tracking, ranking and controlling its entire population.

The fear is that the Chinese government could leverage the data flowing through the parts of the network they build to expand their propaganda and censorship regime beyond China's shores.

A MATTER OF VALUES

Pervasive connectivity of the Internet of Things raises security and human rights concerns, as the confidentiality of citizens' data may be at risk.

Back in 2007, local authorities in Estonia removed a Soviet-era statue; in response, Russian servers paralysed the Estonian banking system. Similarly, if there was a diplomatic or military crisis between Chinese and European powers – whether about Taiwan, Hong Kong or the Uighurs – Huawei may not be able to resist pressures by the Chinese government to disrupt public transportation, industry, or energy grids in Paris, Berlin or London.

> "Huawei may not be able to resist pressures by the Chinese government to disrupt public transportation, industry, or energy grids in Paris, Berlin or London"

A MATTER OF TRUST

To alleviate the UK government's concerns, Huawei opened its source code to selected experts in 2010. So far, audits have revealed poor software engineering practice rather than malicious intent. However, manufacturers can always remotely update the software running on these platforms. Usually, this is done to improve performance, introduce new features or fix vulnerabilities. Yet they could be used to covertly introduce back-door access to the software as well. This is particularly critical for 5G platforms, due to their dependence on software configurability.

At best, it is possible to balance these risks by diversifying providers and

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Huawei's research and development centre in Shanghai, China

segregating virtual networks depending on their sensitivity. Even then, the UK National Cyber Security Centre states they are only able to provide "limited assurance" that the risks of embracing Huawei solutions could be mitigated. It is thus a matter of trust and risk balancing.

A MATTER OF FAIR COMPETITION AND STRATEGIC VISION

One of the reasons why Europeans are facing difficult policy decisions is down to under-investment in research and development of 5G. Huawei has become one of the largest telecommunication companies with tremendous financial capabilities. Huawei spends a third more on 5G research and development than its European competitors, Ericsson and Nokia, combined. But the Chinese government may have helped the company. A recent investigation by US newspaper *The Wall Street Journal* found that Huawei had received $75bn (£58bn) worth of Chinese state aid in various forms.

In early February, France, Germany, Italy and Poland asked the EU Commission to push back against what they deemed to be unfair competition from both US and Chinese firms. But Europe's weakness on 5G, and new technological development more widely, cannot only be attributed to skewed competition. It is as much the result of a lack of strategic vision and industrial policy.

If anything, this controversy emphasises the importance of political will. Without it, in the UK just as elsewhere, market forces are likely to take precedence over considerations of sovereignty or strategic autonomy. **SF**

—

by **ARTHUR LAUDRAIN**
(@APB_Laudrain)
Arthur is a doctoral researcher in cyber security at the University of Oxford. He studies issues at the intersection of technology and international security.

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INNOVATIONS

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↗ The future of city transport? If successful, cars like this by Jaguar Land Rover could be the solution to the impending ban on petrol and diesel vehicles across Europe

INVASION OF THE POD PEOPLE CARRIERS

GM Cruise Origin

This is the first driverless car we've seen that hopes to run tests without a steering wheel or pedals. First, General Motors just has to convince a city authority to let it loose on their streets.

Toyota e-Palette

Like an airport mini-bus, only without a driver who's had three hours sleep, the e-Palette will shuttle athletes and staff around the Tokyo Olympics.

Optimus Ride

Last year this MIT start-up launched the first autonomous pod service in New York. The vehicles ferry passengers around the Brooklyn Navy Yard, a 300-acre industrial park with 10,000 employees.

FIRST LOOK

Jaguar Land Rover trials autonomous car fleet in Coventry

Project Vector will run a fleet of up to 20 'pods' that will ferry students around Warwick University's campus and beyond...

WHAT IS IT? This is a glimpse of where Jaguar Land Rover (JLR), and other car manufacturers, think the future of urban motoring is going. Project Vector is an autonomous shuttle (albeit with a steering wheel and pedals, just in case) that will ferry students around Warwick University's campus sometime this year, eventually taking passengers all the way into Coventry city centre by 2021.

The vehicle uses a skateboard chassis – a simple four-metre long platform with wheels – that can be configured to support different bodies, powered by an electric motor. For now, the car is a six-seater pod, with a top speed of 30mph and a driver at the wheel to help out in the early stages. But the body could be swapped out altogether, to become a inner-city delivery vehicle.

WHY'S IT IMPORTANT? Admittedly, most concept cars rarely make it to the real world. But here's why Project Vector is big. For the most part, autonomous cars have gotten pretty good at learning to drive. But in the future, car companies like JLR anticipate that as well as not wanting to drive, many people won't want to own a car either. Urban populations may come to rely on fleets of autonomous cars ferrying them around city centres instead. If that happens, the most popular services will be the ones that get us from A to B most efficiently.

This isn't just bad news for Taxi drivers. These fleets of self-driving cars will need software that can learn to anticipate demand (like when there's a football match), avoid traffic, and know where and when to recharge its battery. This next phase of learning needs to happen if autonomous cars are to make our lives better, not worse. Especially if you don't want them unintentionally making congestion worse as they coast around town looking for a fare or somewhere to park.

↓ Project Vector is on track for an on-road pilot programme as early as next year

JAGUAR
LAND ROVER

WHAT'S NEXT? This is all part of JLR's Destination Zero mission: zero carbon, zero accidents and zero congestion. It's a lofty mission from a company that makes big SUVs, but Jaguar have been heavily investing in electric car tech, even setting up its own single series motorsport around the I-Pace. And as bans on new petrol and diesel cars come into effect across Europe at earlier and earlier dates, this just seems like judicious planning by the UK's biggest car company.

BUT I DON'T LIKE PODS... JLR aren't the only one to trial this approach to an autonomous fleet. Earlier this year, General Motors unveiled the Cruise Origin, an autonomous 'people mover' that will carry people around cities, only this car has no steering wheel or pedals, and no way for a human to take over, meaning it will need special exemptions from local governments to begin testing.

Meanwhile, last October in London, a more familiar-looking Ford Mondeo fitted with autonomous tech began feeling out the Captial's roads. The trial was carried out by a UK tech firm called Oxbotica, and was the first of its kind. This summer, the company hopes it can begin a trial of a ride-sharing taxi service together with the cab company Addison Lee. Who wants a go?

Ideas we like...

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1. →

A giant-killing trainer

Euclid Chipchoge wore these shoes when he ran the world's first sub-2-hour marathon, and they finally go on sale this month. Their release was delayed, as the World Athletics organisation wanted examine the design before deciding they were race-legal. The trainers rely on carbon fibre plates, foam and 'airbags' – Nike calls them Air Pods – to reduce the energy lost when a runner's foot strikes the ground, quite literally putting a spring in their step. Running pundits believe the arrival of this shoe will see a series of records tumble at the next Olympics.

Nike Air Zoom Alphafly NEXT%, price TBC
Nike.com

← 2.

The lamp's Second Coming

Dyson has a habit of making us reconsider the mundane. In this case, the Lightcycle Morph is a lamp that continually tailors it's light to your age, atmospheric conditions, and the amount of ambient daylight. An infrared sensor turns the lamp on and off as you come and go, and the app offers a suite of usage settings (study, relax, precision etc). Our desk lamp doesn't quite look the same anymore...

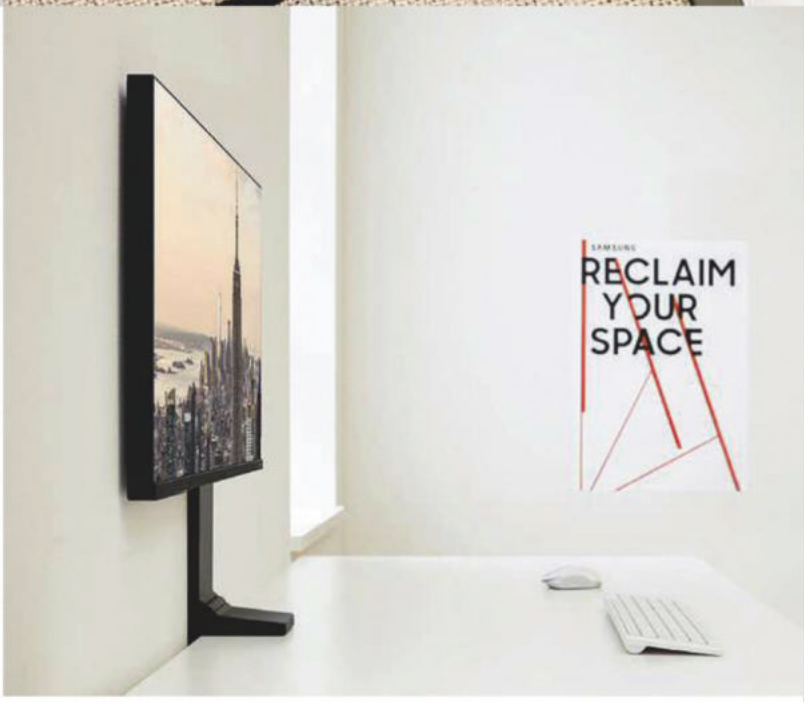
Dyson Lightcycle Morph, £500
Dyson.co.uk

↑ 3.

The return of the flip phone

Flexible screen tech has had a bumpy start. Samsung's Fold 5G suffered durability issues and was promptly recalled and relaunched. Now, Samsung seems to have gotten over that hump with the Galaxy Z Flip. Early signs are promising, but there are concessions to be made – it's not water or dust resistant. Ultimately though, it's a hugely desirable glimpse at what the future of smartphones and tablets could look like.

Samsung Galaxy Z Flip, £1,300
Samsung.com



4.
A space-saving screen

A big monitor can hog your desk real estate, especially if, like me, your workspace is so messy it would make Marie Kondo blush. There's nothing particularly fancy about the Space Monitor, other than the stand which fastens to the edge of your table. It bends right down to the surface it's attached to, freeing up space and helping you pretend you're using a giant monitor aboard the Starship Enterprise.

Samsung Space Monitor, from £449
Samsung.com

↓ 5.
Force Feedback Headphones

These headphones from gaming PC specialists Razer translates sound into, well, vibrations – the kind you feel, rather than hear. It sounds barmy because it is, but in a good way. Like a force feedback controller, the Nari headset hits your ears and face with pulses of vibrations, creating a more 4D experience. The tech is part of a growing field called haptics that has gained a lot of investment and attention as companies seek to create more immersive games and virtual reality experiences. And for the most part, it works.

Razer Nari Ultimate, £199.99
Razer.com

← 6.
Weighted blankets

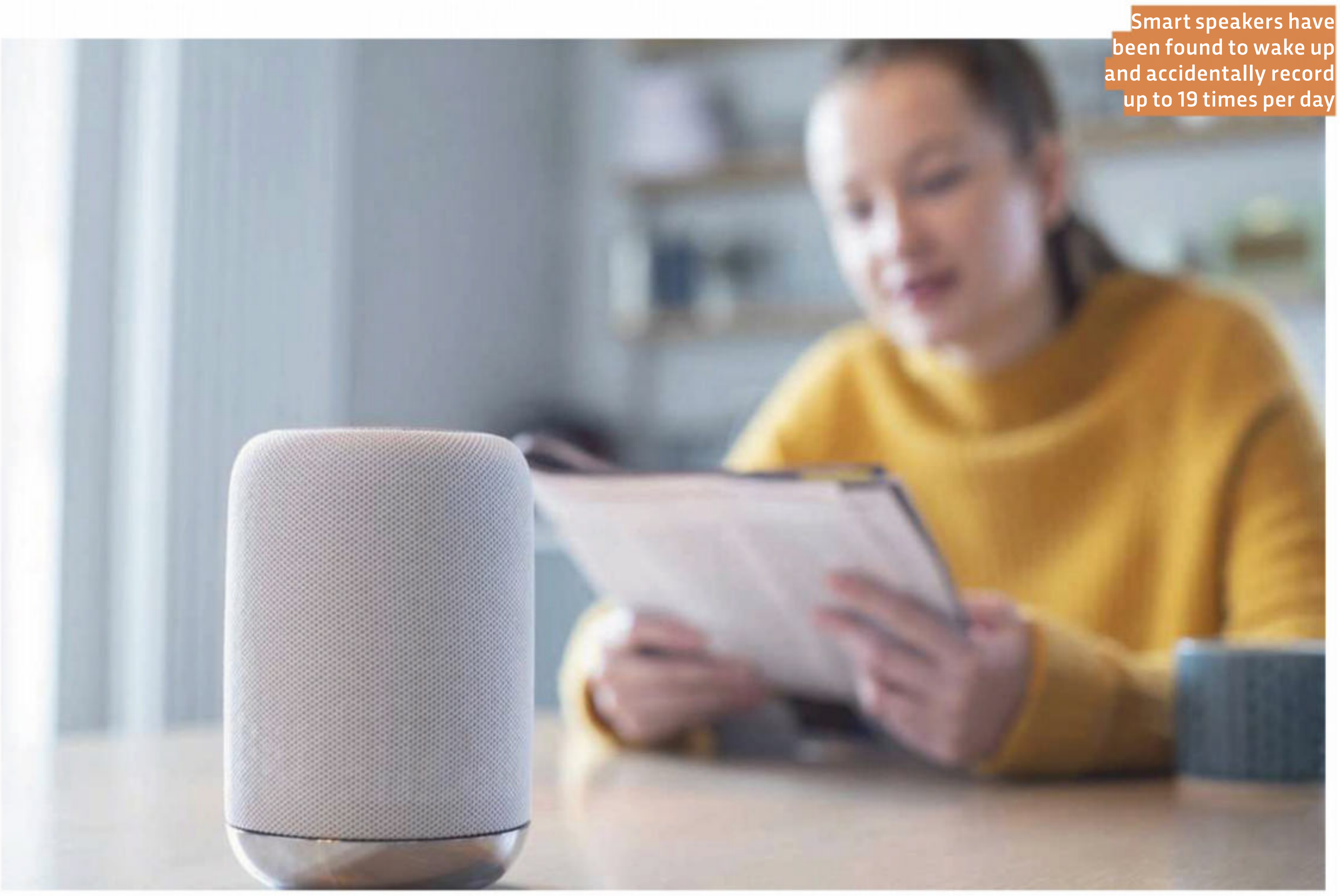
In some small-scale trials, weighted blankets have helped people struggling with anxiety disorders get to sleep. The idea is that applying light pressure, via a blanket that weighs 10 per cent of your body weight, can curb restlessness and feedback to your brain that it's time to get some sleep. We've tried one out and, while a heavy blanket won't appeal to some sleepers, it did *seem* effective on stressful nights when it felt hard to switch off. Simba's Orbit has beads sewn into squares to distribute the weight evenly, so you don't get trapped under a heavy corner. Instead, you're sandwiched between breathable layers that will keep you warm.

Simba Orbit, £149
Simbasleep.com

↓ 8.
An electric dirt bike crossover

This bike blurs the line between battery-assisted pedalling and full-on electric power. Designed for mountain trails, and not the roads, the bike weighs 60kg, which is heavy for a bicycle but light for an electric bike. The battery gives it a range of up to 62 miles, and can manage a max speed of 50mph. And, with 280Nm of torque, it will move like a lightning bolt from a standing start. Now we just have to find a mountain to blast up.

UBCO FRX1 trail bike, €8,999 (£7,527 approx), ubcobikes.com



Smart speakers have been found to wake up and accidentally record up to 19 times per day

Alexa, how often do you listen in?

Ever wondered how many times your smart speaker accidently activates in a day? Researchers from Northeastern University did too, and here's what they found…

> "ONCE ON, THE DEVICES WOULD TYPICALLY RECORD AT LEAST THE NEXT SIX SECONDS OF CONVERSATION"

Voice assistants like Amazon Alexa, Google Assistant, Apple's Siri and Microsoft's Cortana accidentally wake up and start recording what they hear up to 19 times a day.

Anyone who's used a digital assistant knows they have a habit of 'waking up' – making a sound or lighting up to indicate they're listening – when they shouldn't. The systems are listening out for key phrases, or 'wake words' like "Hey Google" or "Siri", before they turn on and start recording in anticipation of a voice query. But these digital eager beavers often jump the gun mistaking the word "seriously" for "Siri", for example, as an invitation to listen in.

The Mon(IoT)r research group at Northeastern University in Boston, USA, are dedicated to investigating what privacy risks might arise from inviting more and more connected devices into our homes. They wondered how many times a day these misfires happened. To find out, they put a bunch of smart home speakers in a room together to watch 125 hours of dialogue-heavy Netflix content, including *Gilmore Girls*, *Grey's Anatomy* and the *West Wing*. Some people get all the good jobs.

They discovered that the average rate of activations per device was between 1.5 and 19 times per day. No smart speaker was found to be consistently recording conversations, but they did wake up for short intervals at inconsistent times. In other words, when the experiment was repeated (12 times) the same phrases didn't always wake up the speaker. Once on, the devices would typically record at least the next six seconds of conversation, though some assistants record more.

So the good news is that the assistants seem to be making honest mistakes, but the bad news is that in some cases they can be recording up to 19 times per day, without meaning to. In further research the team wants to investigate how much of this data is being sent to the cloud, whether these accidental recordings are reported accurately, and whether there are any other factors at play.

GETTY IMAGES X2

THE DOWNLOAD

SWEDEN GOES CASHLESS

The e-krona is coming. It's something of a landmark moment. Sweden's Riksbank says it's begun testing what could become the world's first central bank digital currency. It will be a year-long pilot using technology inspired by the blockchains that power cryptocurrencies.

Sweden is nearly cashless. If you ever visit the country, the first thing you ought to do is download Swish. It's a mobile app that facilitates payments between people and vendors, and its wide adoption has left the country's central bank playing catch up. They fear that if left to the private sector, payment infrastructure might not be built with the best interests of the public in mind.

The one-year pilot will run in an 'isolated test environment'. If successful, the bank will follow up with a public consultation to address any concerns around a cashless future.

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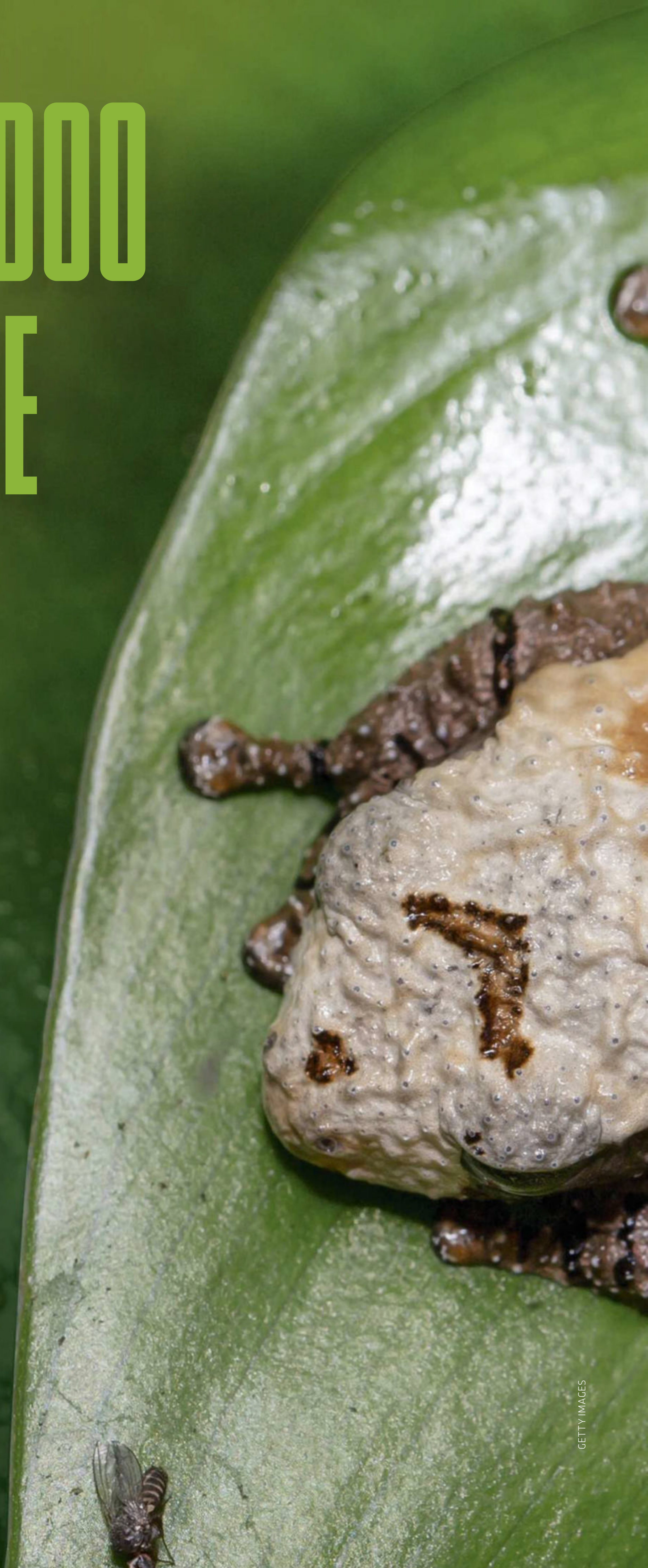
OH, OOBEE DOO I WANNA BE LIKE POO

WHAT'S BETTER THAN HIDING FROM A PREDATOR? LOOKING LIKE SOMETHING THEY WOULDN'T WANT TO EAT IN THE FIRST PLACE. SAY HELLO TO THE SPECIES THAT LOOK LIKE FAECES

WORDS: BEN HOARE

POOP TO CONQUER

In the natural world, a good way of not being eaten is to look like something that has no nutritional value – or, better still, tastes revolting. This sophisticated form of defence is known as 'masquerade'. It's not the same as camouflage – that's simply hiding, says masquerade expert Dr John Skelhorn at Newcastle University. Take this 'bird poop frog' (*Theloderma asperum*) of Southeast Asia. Its predators, such as snakes and birds, may notice it squatting on a leaf, but misidentify it as avian splatter and carry on. "Bird droppings are perfect for masquerade as they're so common in the environment," says Skelhorn, adding that posture is often part of the foolery. "When I held one of these little frogs, it tucked its limbs in so convincingly. It even had the slight iridescence that poo has."



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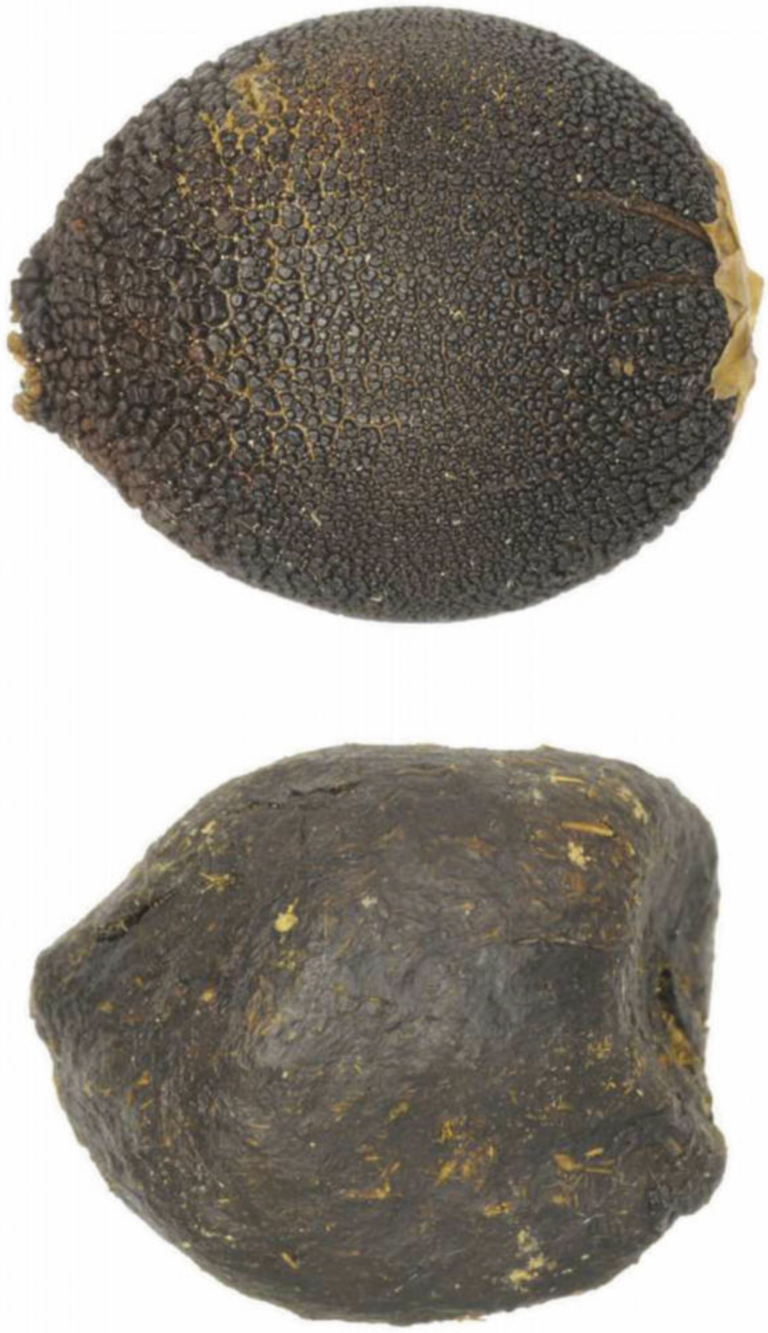
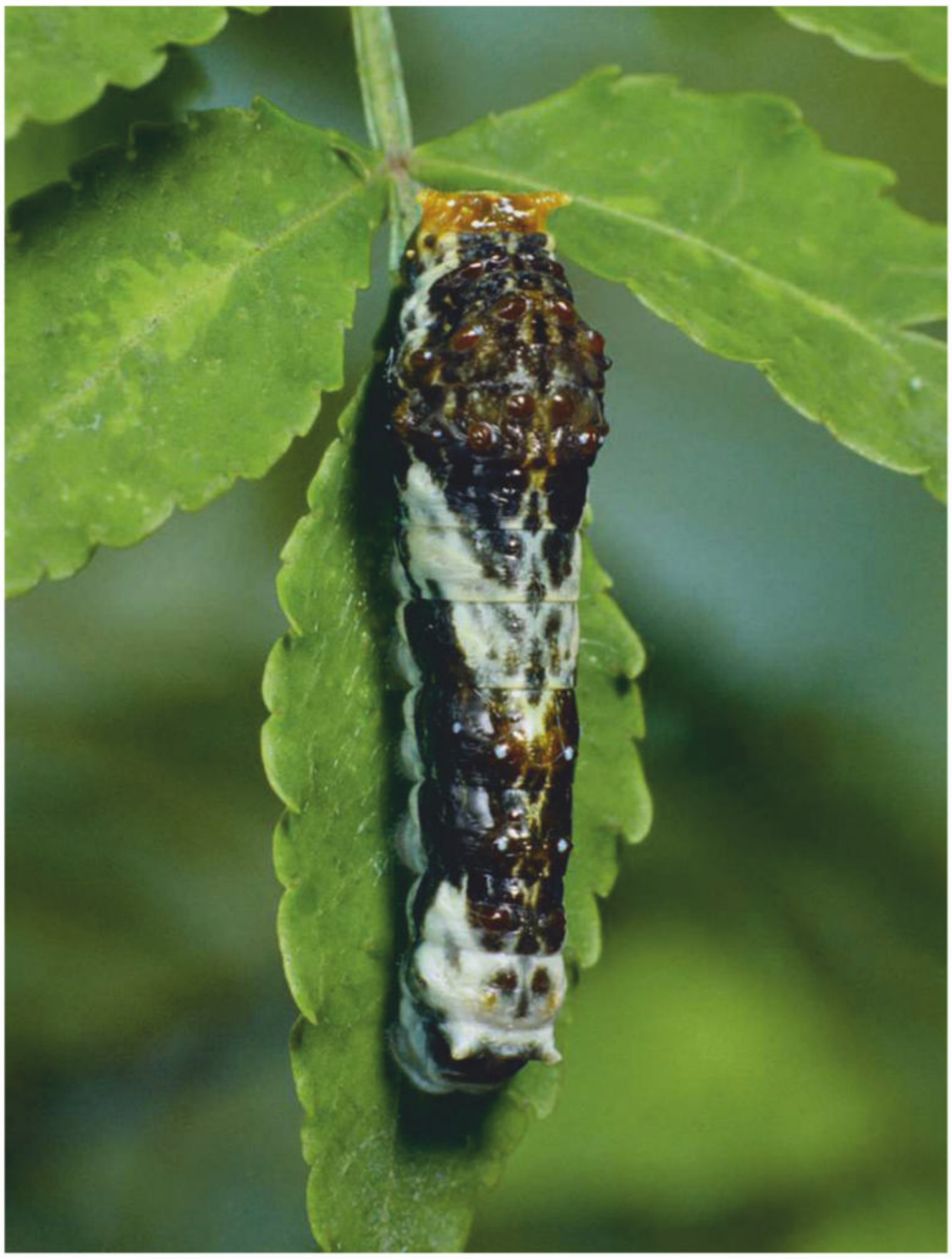


DUNG DEAL

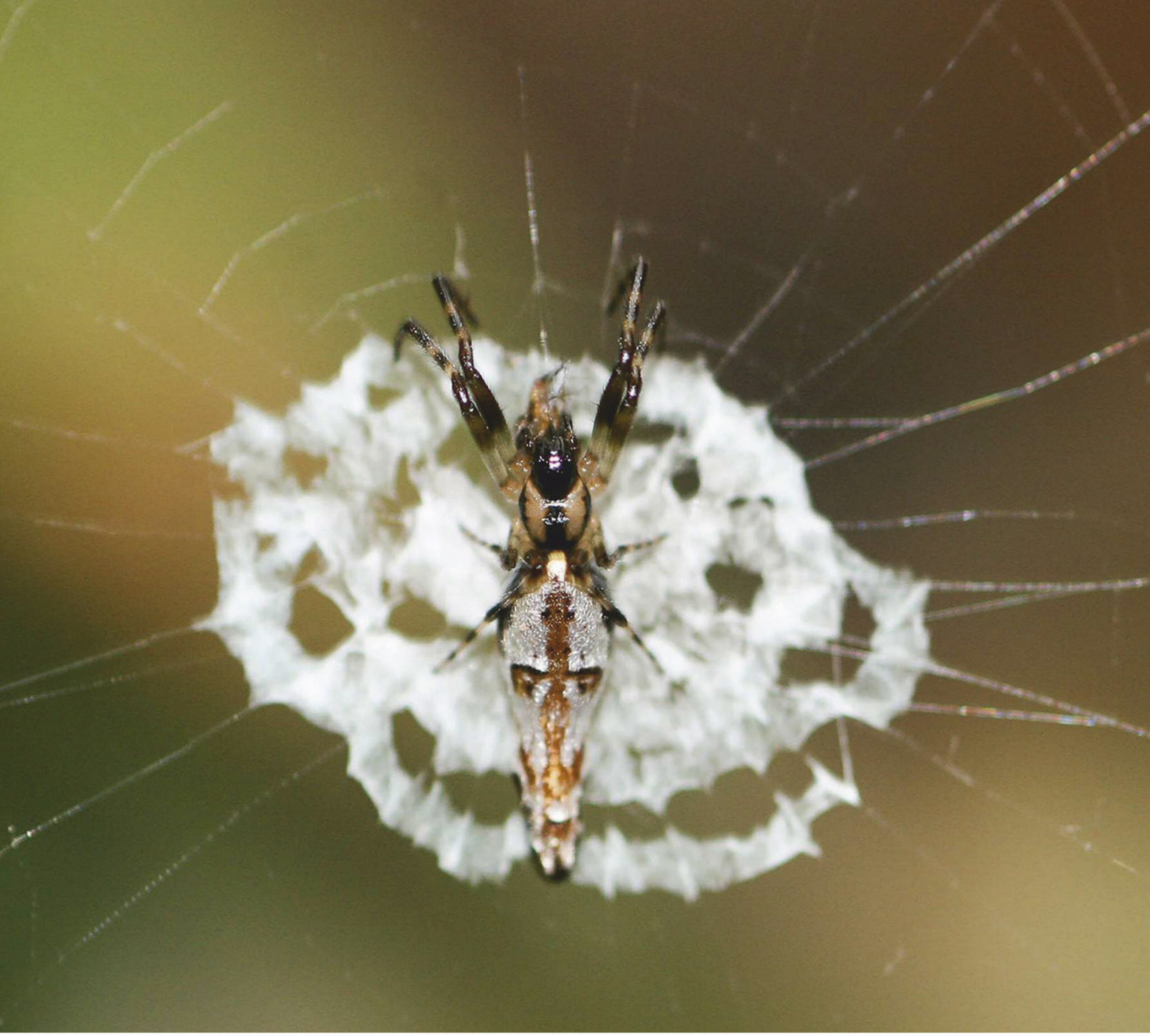
Plants have evolved all kinds of creative ways to disperse their seeds. Perhaps the most remarkable of all, though, is a grass in South Africa's Cape Province called *Ceratocaryum argenteum*, whose shiny, pellet-like seeds (top) mimic the droppings of antelopes (bottom). Within hours, industrious dung beetles scuttle over to roll the 'droppings' away, burying them in the earth (dung beetles bury poo to use as a source of food themselves, or for their larvae to eat). What's more, in order to bamboozle the phenomenal sensory equipment of these beetles, the grass seeds also exude a chemical cocktail that smells like antelope faeces. In 2015, researchers at the University of Cape Town discovered that the dung beetles eventually rumble the ruse and don't bother laying eggs in the seeds. But by then the seeds are safely buried – the ploy works just long enough to succeed.

SPECIES OR FAECES?

Caterpillars are fast-growing munching machines. Their flesh contains more protein than chicken, so it's no surprise they're on the menu of so many insectivorous animals. The Asian swallowtail, or *Papilio xuthus*, is one of several butterflies whose caterpillars fight back by copying the shape, colour and smell of bird droppings. But the masquerade is limited to young caterpillars that don't move around much, such as the one in this photo. Eventually, the larvae are too large and mobile to pass themselves off as poo, so during their final moult they acquire green camouflage and, as an extra deterrent, a pair of scary fake 'eyes'. "The Asian swallowtail displays amazing plasticity," says entomologist and BBC presenter Dr Ross Piper. "When it needs to, its caterpillar swaps tactics and deploys a different defensive strategy." A Japanese study tested models of another species of poo-mimicking caterpillar, and found that they fooled birds only when curled up to resemble coiled droppings; replica caterpillars with straight bodies were toast. It's not clear if the swallowtail caterpillars also have to strike uncaterpillar-like poses in order to survive.



JOSEPH DOUGLAS MANDLA WHITE, MIN HUI LIU, NATURE PRODUCTION/NATUREPL.COM



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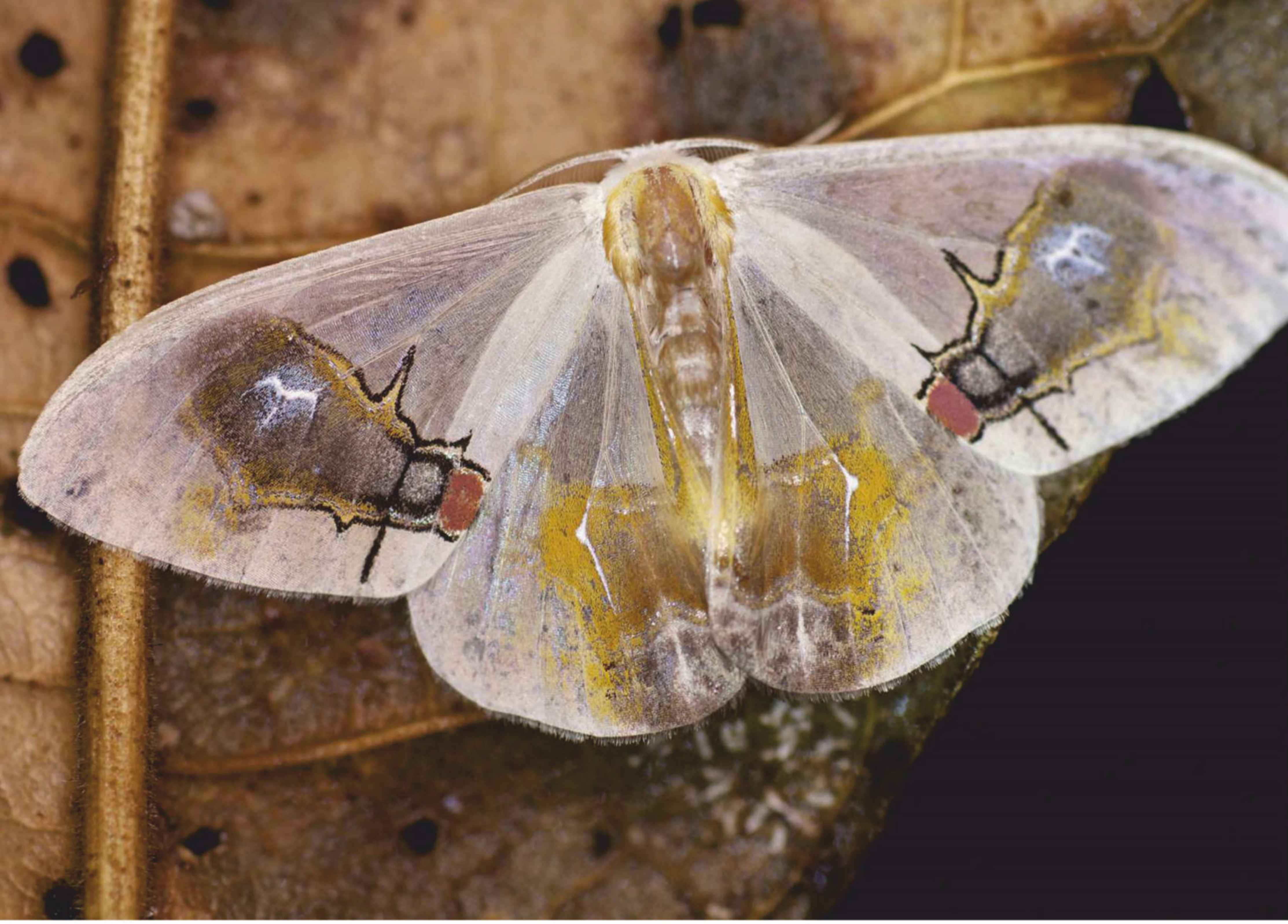
WEB OF DECEPTION

Life for an orb-weaver spider is a balancing act. *Cyclosa ginnaga* needs to attract tasty insect prey, while evading wasps, its main predator. "It is playing a delicate game," says Dr Sara Goodacre of the University of Nottingham's SpiderLab. "Does it prioritise dinner, or defence?" The spider adds a special kind of backcombed silk to its web to imitate splattered bird poo, and this, experiments show, attracts more poo-loving prey, such as flies. It also incorporates bits of leaf and twig, with the same effect. Other experiments have tested whether this technique is a defence, by blackening individual spiders or their webs. They found that darkened (and therefore more visible) spiders were indeed more likely to be attacked, possibly because they looked less like poo. So is this spider using poo mimicry for prey attraction, predator defence, or both? The jury's out. But you can't deny that it's a talented artist.



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STILL LIFE

Adult moths and their caterpillars are masters of masquerade. Excrement is just one of a host of unpalatable things that they replicate, from dead leaves to lichen, twigs, bark and stone. *Macrocilix maia* of southern Asia recreates an entire scene: the adult moth's open wings suggest not only freshly dribbled bird poo, but also two visiting flies, complete with wings, legs and red eyes.

How on Earth does such mind-boggling trickery evolve? "Birds have better colour vision than we do," says Skelhorn, "and they can make out finer detail. So to fool them, there's a strong selection pressure. Over time, you get the evolution of perfection." However, he cautions that there may also be some other trade-off going on. There's been little research so far into this species, and there might be other evolutionary reasons – apart from deception – for why *M. maia* has developed this impressive wing pattern.

→

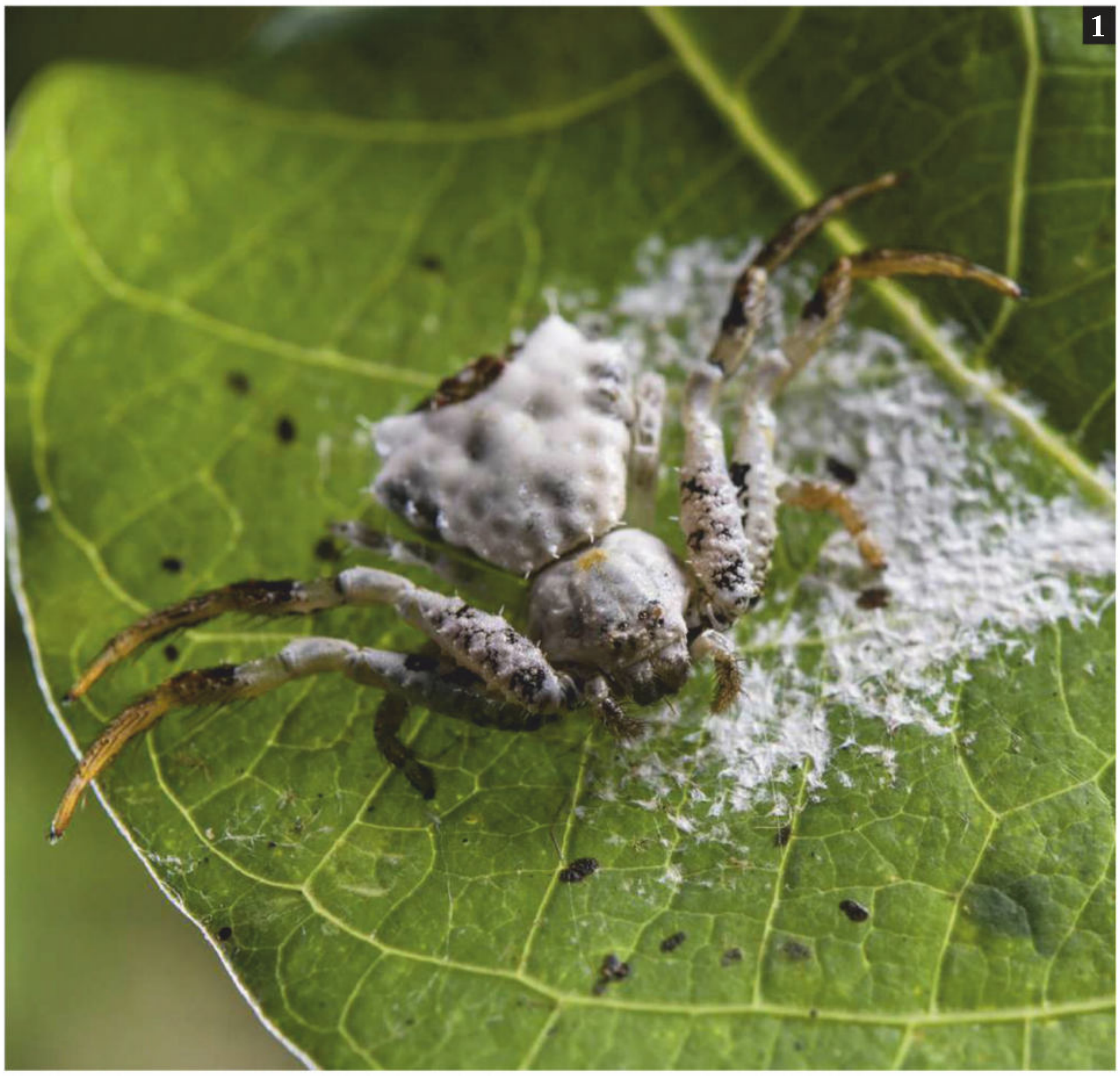
SPOOF SPIDERS

"There are many ways for spiders to look unspidery," says Goodacre, but imitating poo is something at which they excel. Worldwide, several groups of spider are virtuoso faeces mimics, she says. "They clearly have the genetic architecture to masquerade." This subterfuge can involve a suite of physical adaptations, for example, adopting the size, colour, texture and patina of bird droppings.

Some species, such as Southeast Asia's *Phrynarachne decipiens* (**picture 1, opposite**) and *P. rugosa* (**2**) of Africa, heighten the illusion by giving off the whiff of fresh droppings and weaving a messy web around themselves. Poo-mimicking spiders also retract their limbs, changing their silhouette to an amorphous splodge. As Goodacre says: "Extended legs are a giveaway, but you can fix this for free."

The ability of poo-mimicking spiders serves different uses in different species. *Celaenia excavata* (**3**) is a nocturnal moth-hunter, whose camouflage seems to be a daytime defence from predators such as birds. *Arkys curtulus* (**4**), on the other hand, hunts by day and appears to use poo mimicry aggressively, to lure dung-loving flies to their doom. **SF**

PAUL BERTNER/MINDEN/NATUREPL.COM, FLPA DUSTAWAY/FLICKR, EMANUELE BIGGI/NATUREPL.COM X2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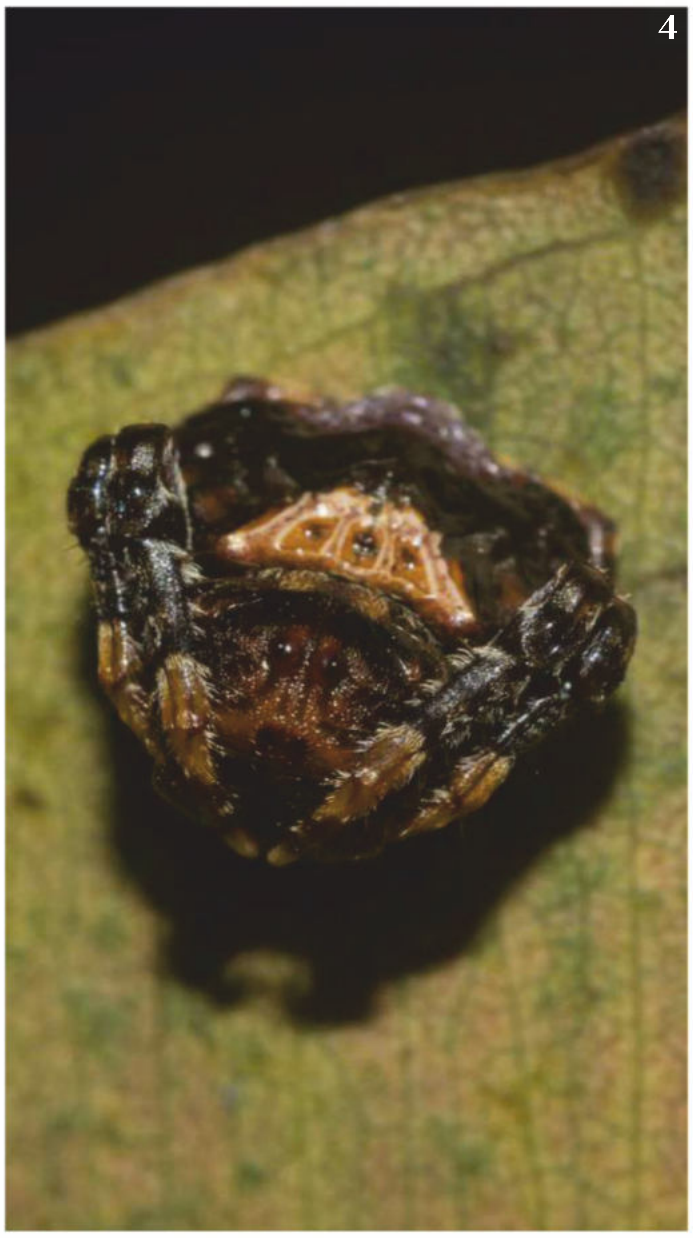
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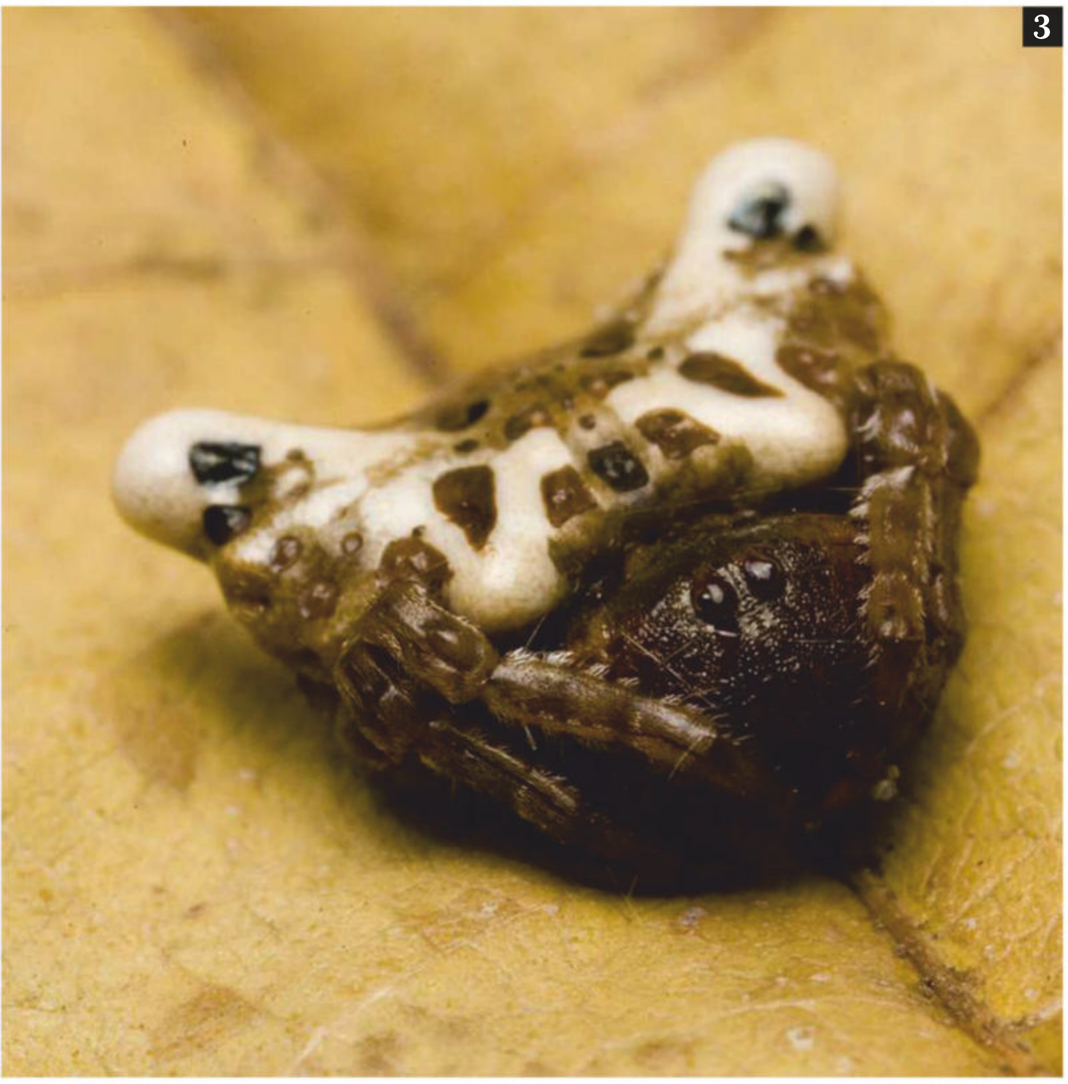
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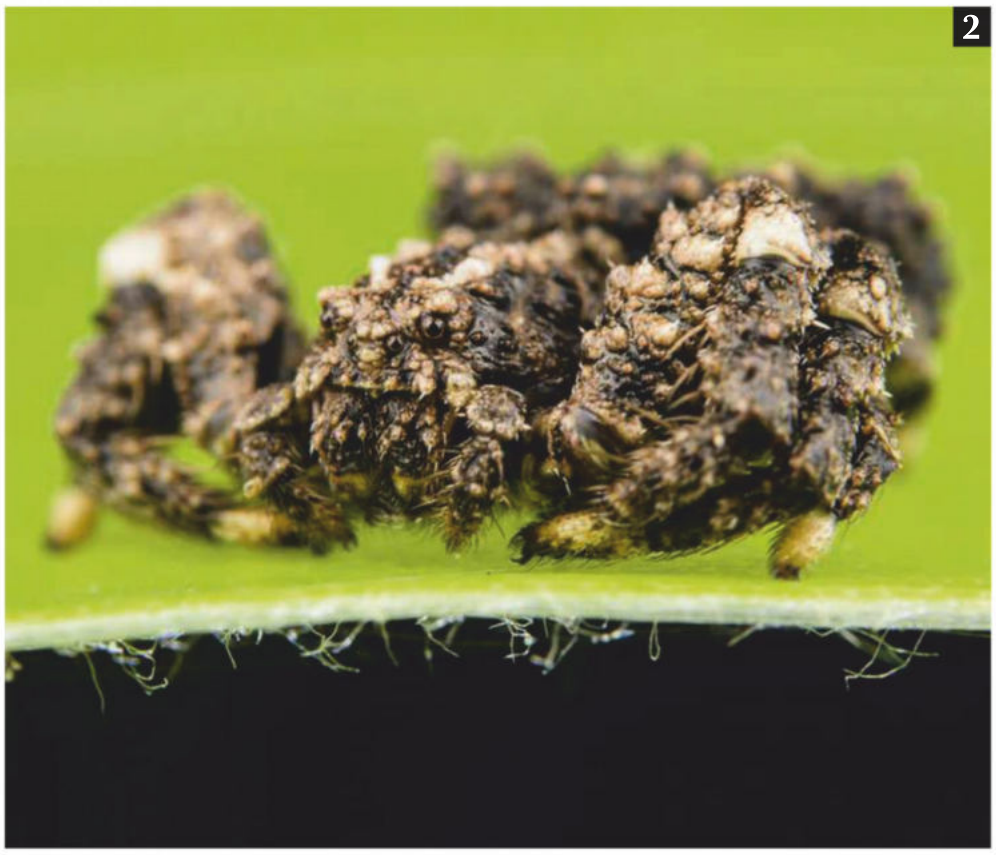
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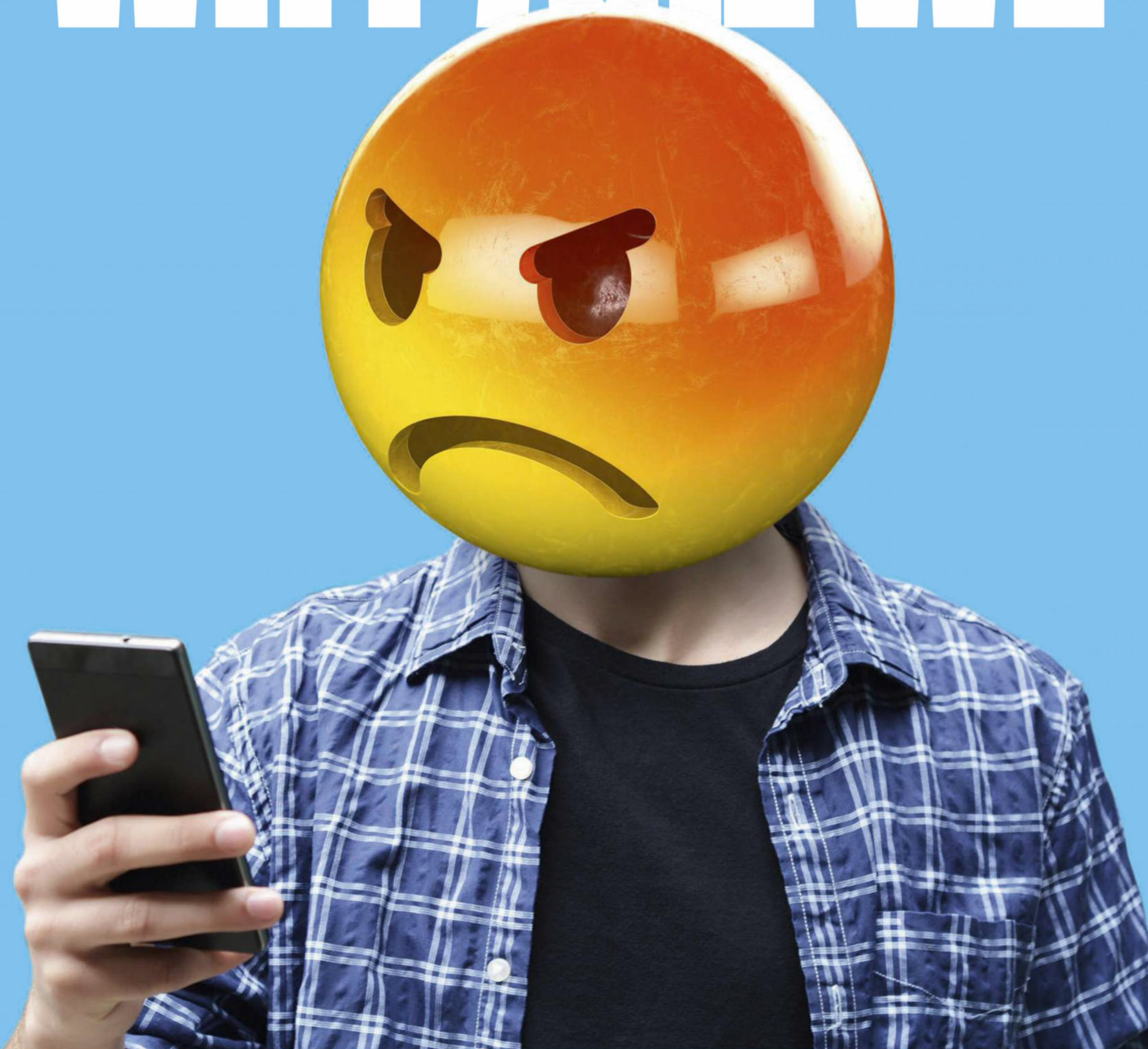
by **BEN HOARE** *(@benhoare5)*

Ben is editorial consultant at BBC Wildlife Magazine. *His latest book is* The Wonders of Nature *(£20, DK Children).*

WHY ARE WE



SO ANGRY?

Every time we glance at our phones or check our social media, we are met by irate tweets and rage-inducing headlines. Why are we all so furious, and is the always-on culture making us angrier?

by AMY FLEMING

GETTY IMAGES/MAGIC TORCH

Outrage has become the defining emotion of the 21st Century, worn righteously, as a finger-pointing badge of honour. From the backlash against Yorkshire Tea, when Conservative politician Rishi Sunak was photographed with a packet of it in February this year, to the outrage from both sides over Brexit, the Twitter hordes are waiting, spring-loaded, to call out anyone who is ideologically opposed to them. Anger is being baited, owned and exalted like never before.

No matter where you stand on each individual case, the outrage and the hungry baying for blood – often with scant attention being paid to context, and with no compassion for someone who may have made a mistake in 280 characters or less – has become a disturbing phenomenon. Sitting anonymously on a bus, anyone with a smartphone has the power to bully, hurl abuse, humiliate and belittle. So is this knee-jerk anger and polarising aggression in danger of seeping out from beyond our screens and into real, flesh-and-blood life? Or, perhaps more disturbingly, are online platforms merely holding a mirror to what was already there?

> “THE OUTRAGE AND THE HUNGRY BAYING FOR BLOOD – OFTEN WITH SCANT ATTENTION TO CONTEXT – HAS BECOME A DISTURBING PHENOMENON”

HOT UNDER THE COLLAR

It’s hard to scientifically measure whether we’re getting angrier or simply venting more publicly. The latest Gallup Global Emotions Report is based on 151,000 interviews with people in 140 countries. Since it began in 2016, the report has found that the number of respondents who felt angry has risen, with the global average currently sitting at 22 per cent. (Anger in war-torn regions is double that, with 43 per cent of people in Palestine and 44 per cent of people in Iraq feeling angry.) However, what psychotherapist and author Dr Aaron Balick can say with confidence is that, in the internet age, “the capacity for emotional contagion of anger has increased, certainly you see anger crossing populations much more easily.”

For example, assaults on Transport for London employees have risen by nearly 25 per cent in the past three years, from 505 to 628, while the RAC’s 2019 Motoring Report found that 3 out of 10 drivers had witnessed physical abuse on the roads in the previous year, with the number of people whose single biggest fear was the aggressive behaviour from other drivers ►

ABOVE People are more likely to exhibit angry, agressive behaviour when part of a crowd

having doubled in 12 months.

Until recently, however, showing anger was a sign of belligerence, or a lack of rational self-control. Most people tried to keep the lid on their simmering rage, as righteous anger was something reserved for God and the clergy. But now, says historian Dr Barbara H Rosenwein, anger has "been secularised and generalised... and everybody's anger is virtuous." Whichever cause you support, whether it's feminism, eco-activism or Brexit, expressing indignation can now feel brave and noble, and is a form of moral superiority. But is it necessarily productive?

SEEING RED

"Aggressive behaviour comes with huge economic costs," says Dr Nadja Heym, a psychologist at Nottingham Trent University who specialises in individual differences, psychopathology and antisocial behaviour. "It has a huge impact on relationships, work performance, mental health, and health in general." While we can't avoid anger arising, allowing it to become persistent and chronic increases the risk of crossing the line into abusiveness. "It's functional to outlet your anger to some extent," says Heym. "[But] what can be dysfunctional is how intensely and how frequently you express it, and how long it takes."

As a basic survival instinct in reaction to a provocation, frustration or threat, anger is a trigger for the fight or flight response. "It's a hardwired emotion which can mobilise us physically and energise us," says Heym. The heart starts racing, adrenaline kicks in and a red mist can descend. To control these animal instincts that are associated with the brain's amygdala, our orbitofrontal cortex provides context, while our frontal lobes monitor and regulate our emotions. But this system can be dysregulated, sometimes through genetic inheritance but also learned through example (such as growing up in a violent household) or poor anger management.

"We have this unpleasant cardiovascular response [when we feel angry] that can raise more negative feelings, and we feel we need to get rid of them," says Heym. Letting it all out in an outburst can bring a sense of relief, but the more we do it, "the more we associate that relief with anger outbursts." This can lead to mindless raging trumping acting more productively on your anger. Similarly, ruminating and stewing will facilitate more angry outbursts. "If we keep ruminating over that anger, and over the triggers that have caused that anger, we carry that negative emotion with us, which can intensify over time," she adds.

> "THE TROUBLE WITH NON-STOP ACCESS TO SOCIAL MEDIA AND NEWS OUTLETS IS THAT OUR BOUNDARIES, IDENTITIES AND VALUES CAN BE ASSAULTED WHENEVER WE LOOK AT OUR PHONES"

Dr Aaron Balick likens being on Twitter to driving. When you're already in a state of mild stress, you're more likely to get angry

GETTY IMAGES X2

ALWAYS ON, ALWAYS ANGRY

The trouble with non-stop access to social media and news outlets is that our boundaries, identities and values can be assaulted whenever we look at our phones, turning all of us into tinder boxes. "You could say that people are chronically wound up," says Balick. He likens this narrowing of our margins of tolerance to what happens when we're driving. "You're in a state of mild or high stress, so if someone pulls out in front of you, you're more likely to scream out of the window. Whereas if you're in a relatively calm state, and the same stimulus happens, you have a threshold to not let it get to you. People who are exposed to angry social media tend to have less margin to contain their anger, too."

Balick has a special interest in social media, having psychoanalysed online behaviour for his book, *The Psychodynamics Of Social Networking*. According to Balick, anonymity is a big part of online anger, with people being more likely to use anonymous accounts on Twitter than Facebook, "You're much more likely to throw out rage and anger, particularly if you have an anonymised account," he says. Similarly, the relative anonymity and security of being in our cars can beget shockingly abusive behaviour, highlighting just how badly behaved we have the capacity to be when we think we can get away with it.

The power of anonymity was shown in a famous experiment in 1970 by Dr Philip Zimbardo, now emeritus professor of psychology at Stanford University. Female students were asked to administer electric shocks to other students, but some of the shockers had their identities hidden with hoods and poor light. No prizes for guessing which group administered twice as many shocks as the ▶

HOW TO DEAL WITH ANGRY PEOPLE: BY A HOSTAGE NEGOTIATOR

Suzanne Williams *is a professional hostage negotiator who has worked with the FBI and Scotland Yard. She has contributed to the successful resolution of hundreds of kidnaps.*

In hostage negotiation, we have a mantra: seek to understand before you can be understood. This is true with angry people, too. First, check your own emotion, as it's the only thing you're in control of. Don't take rude or negative comments personally and avoid escalating your tone of voice to match the other person's.

Allow them to vent, while staying aware of your safety. Being empathetic will often calm them, whereas telling them to relax or calm down will not. Maintain eye contact, to show you're taking this seriously, and don't smile. Proactively listen and try to understand what the issue is. Challenge any threats calmly. Don't say, "You wouldn't do that." You can say things like, "Please don't do that." Don't say that you understand, as you don't know what else has gone on in their day. Instead, try: "So if I understand this right..." to validate your understanding and their concerns.

When you think you've gained some understanding, try to communicate calmly. "I see your point of view," is a good welcomer, or "That must have been frustrating." If culturally appropriate, using someone's name can be a good diffuser because we automatically defer when we hear our names.

CASE STUDY

WHEN INFECTIOUS ANGER LEADS TO PUBLIC SHAMING

In 2013, Justine Sacco, a 30-year-old senior PR officer, flew from New York to South Africa to visit family. Frazzled from travelling, she sent a flurry of sardonic tweets to her 170 followers ahead of boarding a connecting flight at Heathrow. It was one she says she intended to mock her white privilege that got her into trouble: "Going to Africa. Hope I don't get AIDS. Just kidding. I'm white!"

When she landed 11 hours later, #HasJustineLandedYet was trending on Twitter. Members were calling her racist, demanding she loses her job and thrilling over the thought of her face when she switched her phone on upon landing. Someone duly photographed her after she landed and posted that on Twitter too. She subsequently lost her job and became a pariah.

This toxic call-out culture has become somewhat of the norm online. Celebrities are being regularly 'cancelled' (which means losing their followers as people stop supporting) over ill-judged tweets, and many more ordinary people have been fired, even receiving rape and death threats.

What possesses individuals to be so quick to judge and shame? "When you are engaged in social media, it almost feels like it's happening just in your head, so you're likely to be less inhibited," says psychotherapist Dr Aaron Balick. Sometimes, however, people jump in deliberately, "to get off on the energy," or they are seduced by the chance to "bond over giving a righteous justification."

In October 2019, the former US president Barack Obama spoke out against call-out culture. He said that on social media, "[People think] the way of me making change is to be as judgmental as possible about other people, and that's enough … [but] that's not activism, that's not bringing about change. If all you're doing is casting stones, you are probably not going to get that far."

"ONE ILL-JUDGED TWEET GETS RETWEETED DISAPPROVINGLY, GOES VIRAL AND WITHIN DAYS THE ORIGINAL TWEETER IS A PARIAH, RECEIVING DEATH THREATS AND LOSING THEIR JOB"

other. Then in 1976, the psychologist Professor Ed Diener gave 1,300 children the opportunity to steal sweets and money, while they were trick-or-treating on Halloween. They stole significantly more when their identity wasn't known. They also stole more when they were in groups rather than flying solo. Heym says that people are more likely to exhibit angry, aggressive behaviour in crowds, too. "People feel less identifiable, and we feel more confined and intruded into our personal space," she says.

In this way, the infectious anger of Twitter mobs is all too familiar, and it's a terrifying force. One ill-judged tweet gets retweeted disapprovingly, goes viral and within days the original tweeter is a pariah, receiving death threats and losing their job. Meanwhile, the angry tweeters are gleefully getting high on mass righteous justification. If you fire off an angry tweet, getting liked and retweeted might further stoke your rage, which can be thrilling in itself, or it might cheer you up so much that you don't even feel angry any more. "Anger is quite a sensational emotion," says Balick. "There can be a snowball effect where you become attached to the exciting sensation you get through your newsfeed, even if it's an unpleasant emotion like anger, and that that's pretty much what emotional contagion is."

But is Twitter configured to keep the anger flowing? "I don't know about intentional design," says Balick. "What I do know is that hot emotions that set hearts racing, such as anger, fear and sex, tend to be more contagious." If these topics tend to get passed around more, it's likely that algorithms will exacerbate the contagion.

While people might get a kick out of venting on Twitter, Balick doesn't think it's productive. "Processing anger is productive," he says. For example, if you get angry with someone for continuously poking you, and they apologise, this is processing. Talking about it with a friend or partner would also help you process it. "To just shout out into the streets, 'I hate it when people poke me,' triggering other people to say, 'I hate it when they poke me too!'

ABOVE Psychologist Dr Philip Zimbardo was interested in the power of anonymity. In one experiment, he found that when people had their faces hidden, they were more willing to administer electric shocks to other people

DUKE DOWNEY/SAN FRANCISCO CHRONICLE/POLARIS/EYEVINE X2

is not particularly productive. It doesn't go anywhere, it just spreads," he says.

It's hard to find evidence of the extent to which Twitter anger impacts on life off-screen. "Social media is an extension of what is already there," says Balick. Poverty, inequality, mistrust of politicians, threats to reproductive rights, social exclusion and many other real issues are making people angry. "In some cases [social media] may be an accelerator, increasing the anger, frustration and polarisation that is already there." One could also argue that the way we curate our news sources feeds polarisation. "Social media sites like Twitter power up confirmation bias," he says. "You have an opinion on one thing, your natural confirmation bias will gear you towards accepting news and stories that appeal to your opinion, and then Twitter or Facebook further encapsulates you into a filter bubble. It is arguable that this induces and increases a kind of righteous indignation that may indeed lead to a behaviour outside the social network."

AND BREATHE…

There are strategies to help you stay reasonable when angry. "It's all about trying to regulate that strong emotion," says Heym. She says there's good evidence that a method called 'cognitive reappraisal' will help. This means taking a step back from the provocation and trying to see it from a different viewpoint. Focusing on breathing or counting can help. "If somebody nips a parking space away right in front of you, this creates an angry response," says Heym. "You might start muttering or shouting, you might start beeping the horn, some people might get out of the car and attack the person. Trying to reappraise the situation, and learning how to gain prefrontal control over these angry desires, can help."

Trying to repress angry feelings isn't the answer, however. "If you keep your anger in too much and you don't express it, it can backfire," warns Heym. Expending your angry energy by playing sports can be beneficial. Or if you're bubbling over and about to lose it, Heym says that displacing your angry response can help avert catastrophe. "Hit the car seat rather than getting out of the car and hitting a person," she suggests. "Just to get rid of that intense outburst that you're feeling at this moment, because losing control can come at huge costs."

Mindfulness has also shown promising results. It helps train your mind to see and understand what's happening in the moment, without reacting. "The more you practise mindfulness, the better you get at it," says Heym. "You learn that these negative emotions are transient experiences. Our heart rate shoots up, we are adrenalised and we want to react, but observing your own state helps you to see how this is transient and goes away and then we can deal with the problem in a much more efficient manner."

Verbal aggression, says Heym, can be as hurtful as violent aggression. Whether you're about react to a confrontational tweet, an overtired child or being beeped at while driving, the message is, "Try to take a step back, take a breath, remove yourself from that frustration point, and cognitively reappraise before you act." **SF**

by **AMY FLEMING** *(@amy fleming)*
Amy is a freelance science writer and editor.

THE THINGS SCIENCE HAS TAUGHT ME

When computers are taught to solve complex equations or run algorithms, their processes mimic the methods of the human mind. It follows, then, that we could learn more about ourselves from machines. **DR CAMILLA PANG** *talks to* **AMY BARRETT** *about how she uses science to understand the world around her…*

Photography: **Steve Sayers**

> “To be neurodiverse and show it, takes a lot of guts. You have to know how to train it, to use it, and not be hindered by being an odd shape”

Camilla was diagnosed with autism spectrum disorder when she was eight years old. She struggled to understand the world around her, and once asked her mother if there was ‘an instruction manual for humans’. Her first book, *Explaining Humans,* is a guide to navigating life, love and relationships using the lessons she’s learned in her scientific career so far, drawing on examples from how the different proteins in the human body can reflect the different roles in a social group, to the way how light refracts through a prism helping her to break down fear into something manageable.

IN WHAT WAY DO YOU STRUGGLE TO COMMUNICATE?

Well, firstly open-ended questions aren’t my forte, I think that’s quite important to know. This whole book highlights why open-ended questions are hard; I’m on the autistic spectrum and I also have ADHD, but that doesn’t define me. I don’t fall victim to my neurodiversities. They empower me and I wouldn’t have been able to do my PhD or write my book, *Explaining Humans,* without them.

WHAT IS THE BIGGEST THING THAT HAS SCIENCE TAUGHT YOU ABOUT HUMANS?

Science is still teaching me. It’s not a concrete thing and this is one of the reasons why I’m in love with it. It’s something that is ever-evolving, and so are people.

It’s very fluid, that’s one of the lessons it has taught me. I like to be on the cutting edge of science, and I think that inadvertently makes me more fluid as a person, and less rigid.

WHERE DOES SCIENCE INTERSECT WITH HOW WE MAKE DECISIONS?

Take machine learning [using patterns in data to generate algorithms that can predict future outcomes]; it’s inherently based on psychology. That’s what we’re trying to do, to mimic the human brain and then scale it up so we can gather some kind of insight and intuition.

Machine learning uses what we know to anticipate what we should do in unknown circumstances, aka the future. They aim to replicate the convoluted logic and decision-making processes that happen at smaller scales, but ever so accurately, in the human brain.

But currently, as much as AI can iterate data until the cows come home, humans are much more superior, albeit slower, at decision making.

Our decisions are a tad more involved and layered than computers. Neurotypically, we don’t refresh our biases every time from random. Rather we gather them through experiences, errors and successes, which fine-tune our intuition to infer outcomes.

HOW DOES YOUR KNOWLEDGE OF MACHINE LEARNING HELP YOU MAKE DECISIONS?

Imagine I am a committed Uber Eats user and have a strong sense of routine (which isn’t too far off). The app in question may predict a suggestion and cater – quite literally – to my needs, the evening before I’ve even opened the app. The same logic could be paralleled in the attempt to anticipate the whims and woes of close friends or partners, which is more of an experienced, convoluted and recursive process. Or in decisions that concern many people. Things like; do I, or do I not react to when someone is really annoying me? Or, what kind of thing do I say when someone needs a hug? These decisions are nuanced and require some level of known experience, some learning from mistakes and a degree of self-reflection.

This imitates a more snazzy version of AI: deep learning. Deep learning is an adaptive, reinforced training, an expertise acquired purely through its freedom and ability to learn from its mistakes. Although, deep learning operates in an accelerated and low pressured environment, where housework and the fear of human judgment doesn’t get in the way.

SO, IS THERE REALLY ANY SCIENCE BEHIND MY FAILED RELATIONSHIPS?

I don’t like the word ‘failed’. I think that’s a very binary way of thinking. I mention this in chapter one of *Explaining Humans*, it’s box thinking, and you’re either one or the other. You fail or you succeed. But evolution is a bit more flexible than that, so a failure in one context ▶

DR CAMILLA PANG

Camilla completed her degree in biochemistry at the University of Bristol, and went on to gain a PhD in bioinformatics from University College London. Her current work uses disease and cancer data, along with machine learning methods, to find patterns that can be used in healthcare and lead to the development of therapies. Camilla is an active volunteering researcher for cancer research groups at the Francis Crick Institute in London, and also works on her own projects within psychology, science communication and the arts.

is often a treasure in the next. That's actually kind of nice, because it gives us that wiggle-room we need and that open-mindedness to say, you know what? Let's cut ourselves some slack. If it's not working, it's not working.

We are all evolving, and to be able to evolve together is great, but to evolve separately and through different means is also great. It's our energetic potential as people.

YOU'VE MENTIONED NEURODIVERSITY, WHICH IS OFTEN COMPARED AGAINST NEUROTYPICAL. CAN YOU EXPLAIN WHAT THESE TERMS MEAN?

People commonly refer to 'neurotypical' as someone who is not yet diagnosed with a mental health variance. I don't call it disorder, because I believe it is clearly imposed by environment.

Neurodiversity is a term that is quite closely related to autism, ADHD, bipolar and schizophrenia; all those different types of psychological impositions that can affect you. What you find with these mental health variances is that a lot of the struggles that people have, are mainly due to the intolerances of their environment.

If left alone, I'm normal. I'm fine. Happy as Larry. But if I had to sit at my desk in a certain way all day, I'd go absolutely nuts. I actually sit under my desk – I've got a standing desk – and I read there. The people at my work are very accepting of that. So, what I'd want everyone to know about neurodiversity, is to just accept and embrace it.

Honestly, I think everyone is neurodiverse. Even though you try to be square, you're not square. I'm very sorry to tell you, it doesn't exist. You are a species on this planet and you are subject to evolution. You're going to evolve but to admit to that, and to behave as your natural self, is sometimes quite hard with these kind of social constraints.

So, neurodiversity is something we're all faced with. Some of us just know how to hide it better, because they either feel it less, or maybe because they're more scared. To be neurodiverse and to show it, that is actually very brave, and takes a lot of guts.

You have to know how to train it, to use it, and not be hindered by you being an odd shape. It's easy to feel squeezed and trapped. I'm speaking from my personal experience and everyone who has a diagnosed mental health

> "ADHD can make you feel lost, and so can autism, but together, somehow, you find your way through. It's almost like magic"

ABOVE Camilla Pang (right) talks to Amy Barrett from *BBC Science Focus* about neurodiversity

variance will have their own experience.

But being adaptable to your own needs is key, and I think that can be said for everyone, not just those who are neurodiverse.

WHY IS AUTISM CLOSELY LINKED WITH ADHD?

They are a marriage made in heaven, but they live in hell. They are counterparts. To be honest, ADHD's a kind of chaotic, unpredictable, sporadic, wildfire that spins outwards, and it's everything that makes you feel alive. It's messy, and it's not routine. It's fluid.

Autistic spectrum disorder is more rigid. More focused. It's like routine. It's very introspective. From my experience, that is.

They save each other a lot of the time because they're a yin and yang. Most of the time I feel like I'm a third wheeler. I really do. I'm mediating both of these psychologies simultaneously, and I'm like, "I just want to make a cup of tea."

But the good thing is that they do complement each other. I go into hyper-focused mode, and I've also got my Asperger's to push that through further, so I get stuff done fast. ADHD can make you feel lost, and so can autism, but together, somehow, you find your way through. It's almost like magic.

I think it's very important to highlight the intersection of anxiety. One can save the other, but also, they can act together to create a really powerful anxiety. That can be hard to deal with. You don't know what you're going to be anxious about that day, but you know that your mind is spinning in both directions. You just have to learn to train it. It's energy, at the end of the day.

HOW DO YOU FEEL ABOUT THE WAY AUTISM IS PORTRAYED IN THE MEDIA?

It's not quite accurately represented in terms of how varied autism can be. It's very male-orientated. It's a very white culture, and there are lots of heads banging on walls. And I think that's due to the fact that we don't know what [autism] looks like in any other form because it's very hard to diagnose.

It's symptomatic, and it's very, very varied. People who have it, particularly females, are known to mask their symptoms, so trying to get it out of them is really hard. Lucky for me, I was diagnosed at the age of eight or nine.

But for example, when someone says to me, "Oh, Millie, you don't look autistic!" I know that they mean well, so I don't make a fuss. I give an indifferent answer that I've rehearsed, obviously.

But it's degrading to say I don't look autistic because it's not something that I have; it's something that I am. This is my human shape. I am autistic, and I have a different shape. I experience life differently, to the point where it can hinder, but it can also enhance my experience.

I'm really hoping that this book sheds a light on how varied [autism] can be, but also anchor it down to a common psychological route that explains why you are feeling a) that little bit weird or b) out of place or c) to explain the human that you are.

WHY DID YOU CHOOSE TO WRITE *EXPLAINING HUMANS* NOW?

Explaining Humans is my attempt to write a manual from the pieces of information I'd assembled since I was a child, but I didn't know I was writing it. It started with the notes I had collected, and like bobbles on a jumper, you're a little bit embarrassed by them, but they are inevitable and I couldn't *not* write it. I had to write to survive, and assembling these notes enabled me to decode and connect with humans.

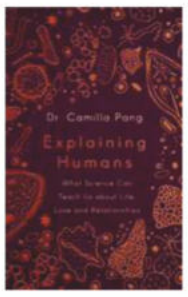
It's also an attempt to make science visible for people, as it actually made people visible to me. I can be myself with science, and it's something that I want to share with others because it's how I understand them.

Thinking about it, I used to have visions of myself, wanting to give it to my mother when I was little. So I could one day be like, "Here mum, this is what's happened. This is why I couldn't communicate, and now I can." **SF**

DISCOVER MORE

ON THE PODCAST *Subscribe to the* Science Focus Podcast *to listen to our full conversation with Dr Camilla Pang in an upcoming episode.* ***sciencefocus.com/ science-focus-podcast***

READ Explaining Humans *is out 20 March 2020 (£14.99, Viking)*



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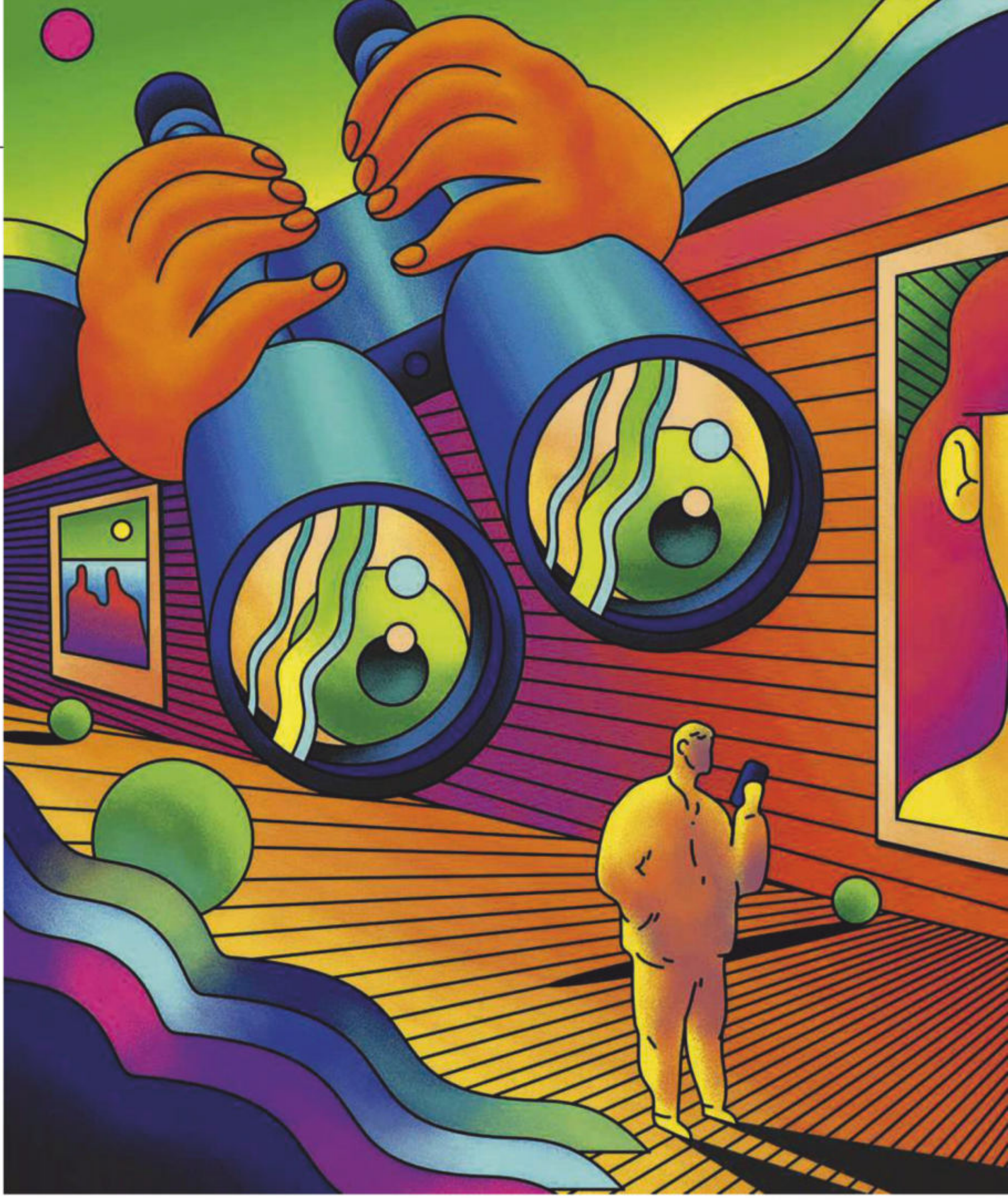


COMMENT

STOP SNOOPING!

Before meeting someone new, do you look them up online to find out more about them? That's not a great way to start conversations…

Have you ever looked up your friends online? Scrolled through their updates, binged on their Insta, read an ancient blogpost, or even gone down the rabbit hole and found their first profile pic? How'd it make you feel? Closer, or creepy? Dirt-digger, or voyeur? Or are you a person who refuses to go there on principle, preferring to allow friends old and new to reveal their hobbies, likes, dislikes and opinions to you at their own pace?

I'm part of the latter camp. I get really creeped out when I discover that someone's looked me up online, so I try not to do it to anyone else. An article by Justine Gangneux in the September 2019 issue of the journal *Information, Communication & Society* says I am unusual. She reveals how normal it's become for people in their 20s and younger to screen potential new friends by trawling through a person's social media profiles, and cross-checking with other accounts just to make sure they've got the correct information.

I don't want a dossier on a random person my mate thinks I should meet. If my mate thinks I should meet someone, I trust them. And I trust that the person I'm going to meet will talk about stuff they find interesting, rather than wait for me to prompt them with targeted questions.

But I am old, and weird in my social media profile fact-checking aversion. I get why it might be something you'd do. I had a friend who, years ago, was newly single and was exploring online dating. She met someone she hit it off with, and was considering meeting up with him. But she then discovered through a bit of archaeological digging that he'd been accused by his ex-partner, and several other unrelated women, of sexual assault. That's a good example of why you would want to check up on someone.

> "The amateur surveillance that we all do (me included) hides a fear of vulnerability"

But what Gangneaux writes about goes beyond safety management. She explains that pre-checks of mutual acquaintances allows the person snooping to make guesstimates about whether meeting this person would be a waste of time and emotions or not. Because meeting the wrong person for a 30-minute coffee can be such a bummer in your busy life.

Her participants feared lulls in conversations that would have to be filled with clarification questions. They wanted to avoid having to engage with someone they didn't agree with. They poked around profiles to check political affiliations, match music and gather talking points. Stuff you can find out in 15 seconds face-to-face, but can make the remaining 29 minutes and 45 seconds feel like an eternity.

The amateur surveillance that we all do (yes, me included) hides a fear of vulnerability, and an aversion to different opinions. This is how the internet's filter bubble transfers offline. It's also how we find ourselves so emotionally bruised when we discover that the rest of the world doesn't think like we do.

So next time you're tempted to do a little digging, resist. Allow the other person to be in charge of the direction that conversation travels. You might discover you're open to learning something new. **SF**

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

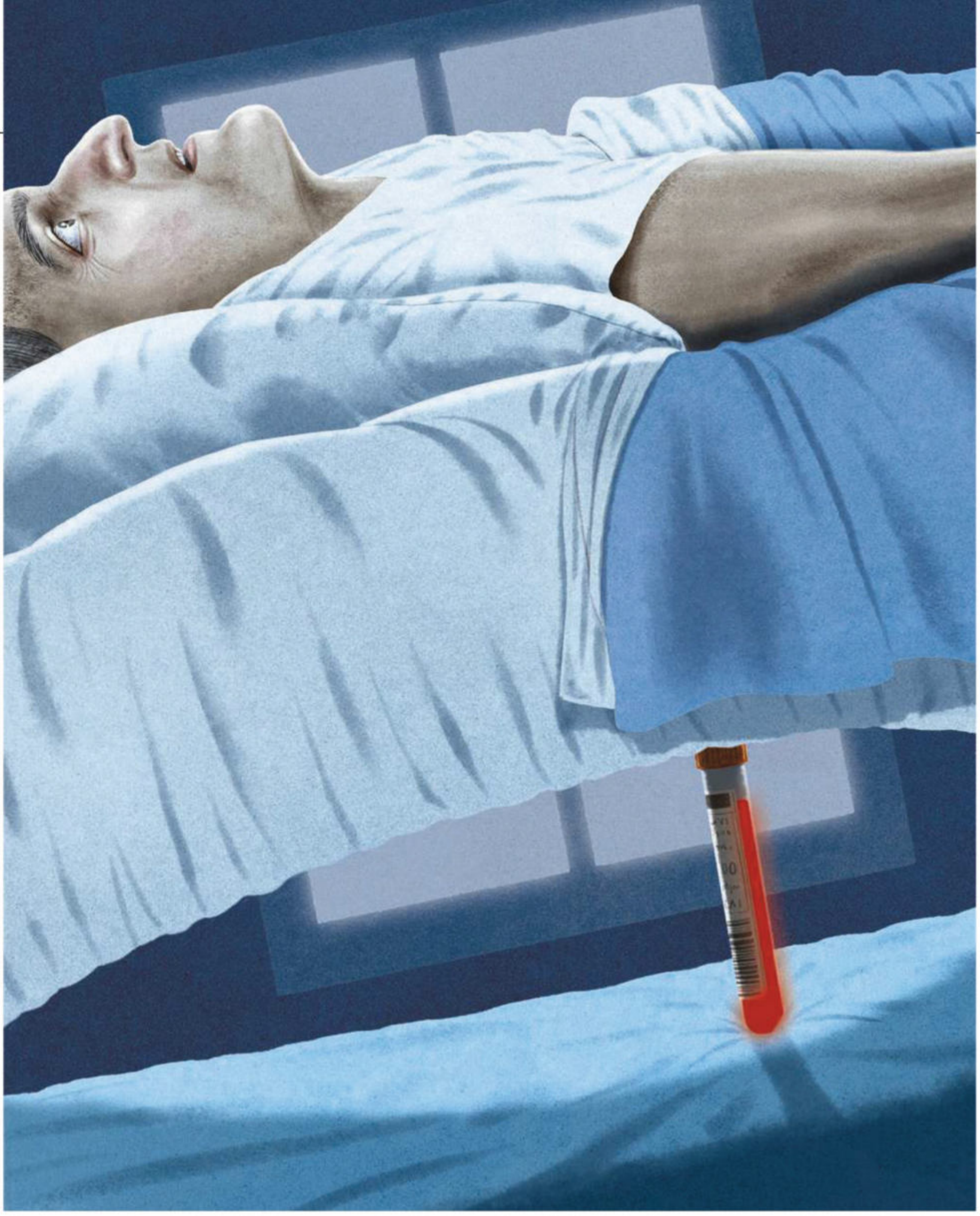
BBC RADIO 4 92–95FM & 198LW

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

COMMENT

PROBING THE PROSTATE

Health tests may be useful, but they can also lead to anxiety and false positives



A few years ago, I made a film about health tests for BBC's *Horizon*. I put myself through a battery of health tests to see which, if any, were worth doing. These tests included things like having my blood pressure tested, a CT heart scan (only available privately), the prostate specific antigen (PSA) test for prostate cancer, and bowel scope screening (they stick a camera up your backside to detect early signs of bowel cancer).

I concluded that having my blood pressure tested and my bowels screened were a really good idea, but that many of the other tests I did were more likely to induce anxiety than find out anything worthwhile.

The PSA test for prostate cancer is a prime example of a test that can do more harm than good. The reason for doing it is that prostate cancer is a major killer. While breast cancer deaths have reduced by a fifth over the past 10 years, the number of men dying from prostate cancer has increased by 18 per cent. Within the next 10 years, prostate is predicted to become the most commonly diagnosed cancer in the UK.

So you can see the pressure to detect it early. Yet not only does the PSA test throw up lots of 'false positives' (telling you that there might be something there when there probably isn't), but it also warns you about the presence of cancers that would never actually impact your life. Autopsies show that something like 70 per cent of men over the age of 80 have prostate cancer, but most will die of something else.

> "The PSA test for prostate cancer is a prime example of a test that can do more harm than good"

My father is a prime example. He had a PSA test in his early 70s and was told he had prostate cancer. He had invasive surgery to get rid of it. The impact of the surgery blighted the last years of his life. It's possible the treatment slowed the disease, but it is also possible that it was a slow-growing tumour and he would've died never knowing he had it. In fact, he died of unrelated heart failure a few years after the operation.

Several randomised controlled trials have shown that if you have a slow-growing tumour then it is better to watch and wait than to have surgery, radiation or hormone therapy. But how do you know if your tumour is growing slowly?

The good news is that tests which can discriminate rapidly growing cancers from more benign forms are becoming available. These include something called a 'multi-parametric magnetic resonance imaging' (mpMRI) scan, which creates more detailed pictures of the prostate than a standard MRI scan. These are available on the NHS, and recent trials have shown that having an mpMRI scan reduces the chance of unnecessary biopsies and aggressive treatments.

Since biopsies and over-treatment often lead to impotence and urinary incontinence, I will be booking myself in for an mpMRI should the need arise. **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* You can watch clips at **bit.ly/trust_me_clips**

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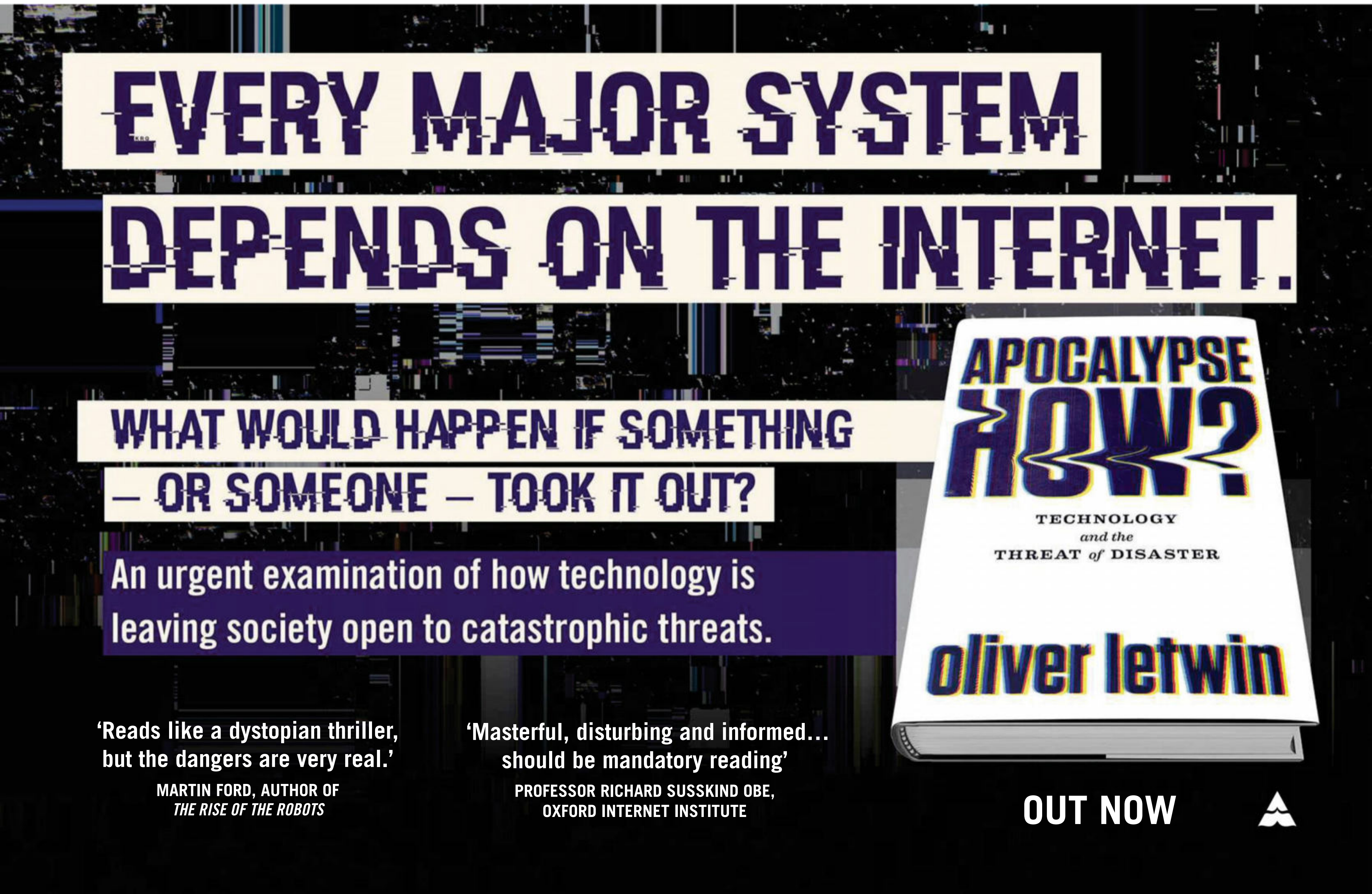

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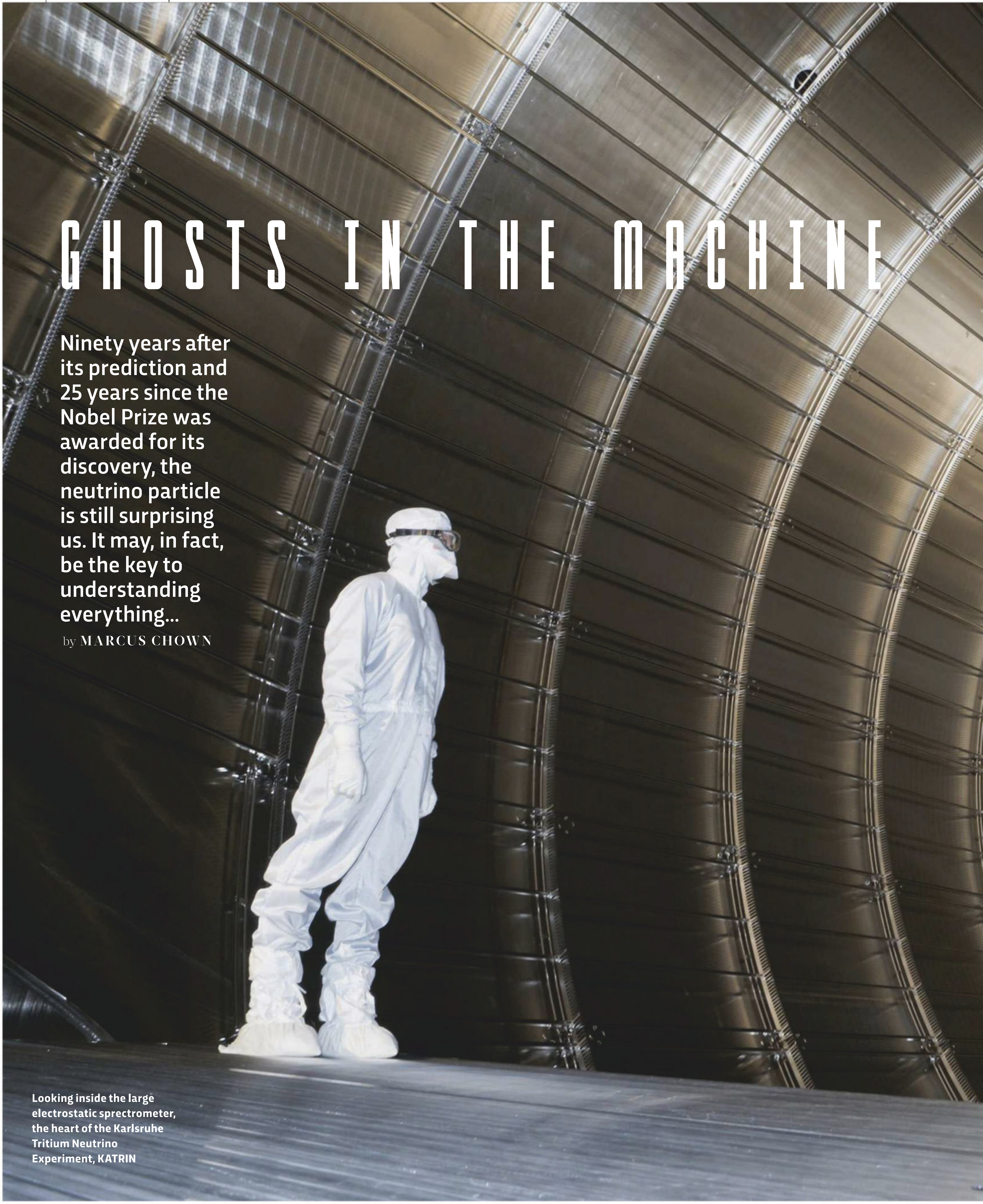

GHOSTS IN THE MACHINE

Ninety years after its prediction and 25 years since the Nobel Prize was awarded for its discovery, the neutrino particle is still surprising us. It may, in fact, be the key to understanding everything…

by MARCUS CHOWN

Looking inside the large electrostatic sprectrometer, the heart of the Karlsruhe Tritium Neutrino Experiment, KATRIN

Listen to *Big Bang Day: Five Particles*, presented by Simon Singh. These five radio programmes explore the significance of subatomic particles.
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MICHAEL ZACHER

Physicists are homing in on the mass of the neutrino, nature's most elusive subatomic particle. The latest super-accurate measurement, made by an experiment in Germany, shows that the neutrino is around half a million times less massive than the electron, the lightest particle of normal atomic matter. According to the Standard Model, the high point of 300 years of physics which describes the fundamental building blocks of matter and three non-gravitational forces that glue them together, the neutrino should be massless. So why should we care about a mass measurement (no matter how tiny) of a neutrino? Well, it may provide vital clues to the fabled 'theory of everything' – a deeper, more fundamental theory of physics of which the Standard Model is believed to be but an approximation.

HUNTING THE ELUSIVE GHOST PARTICLE

The latest neutrino measurement was made in Karlsruhe, Germany, where physicists exploited the 'beta decay' of tritium. Tritium is a heavy type – or 'isotope' – of hydrogen. In beta decay, the unstable core – the 'nucleus' – of an atom sheds surplus energy by spitting out an electron and an antineutrino (the neutrino and its 'antimatter' twin have the same mass). Neutrinos are fantastically antisocial, interacting so rarely with normal matter that they could pass unhindered through several light-years of lead. Consequently, the physicists at the Karlsruhe Tritium Experiment, or KATRIN, must infer the neutrino mass from measurements made on their electrons. They can do this because the amount of energy emitted by the tritium nuclei is always the same. The energy is divided between the electron and the neutrino – if an electron has lots of energy, then it must mean that its associated neutrino only has a little bit. So if the physicists only allow the most energetic electrons to reach their detector, it ensures that their associated neutrinos will have very little energy – this allows them to make a more accurate reading of the neutrinos' mass.

KATRIN is an extraordinary piece of engineering. After 18 years of planning and building, it weighs 200 tonnes and cost about €50m (£42m). It is operated by a team of 150 people from six international institutions, and yielded its first result after only one month of operation after observing two million electrons. The experiment found that the neutrino cannot weigh more than 1.1eV (because Einstein showed that mass is a form of energy, physicists measure the masses of subatomic particles in energy terms – an eV is an electron volt). By comparison, an electron has a mass of 500,000eV. "The result is an incredible achievement," says Dr Melissa Uchida, a neutrino physicist at the University of Cambridge. "The uncertainty in the mass limit is 100 times better than the previous best estimate."

There is a twist to this story – a major one. The electron-neutrino is merely one of three types, or 'flavours', of neutrino. The electron-neutrino is associated with the electron, but there is also the muon-neutrino associated with the heavier 'muon' particle, and the tau-neutrino with the even heavier 'tau' particle.

There are three distinct mass states of the neutrino. But, crucially, each does not correspond to a flavour – in fact, each neutrino ➲

KATRIN COLLABORATION, GETTY IMAGES X2

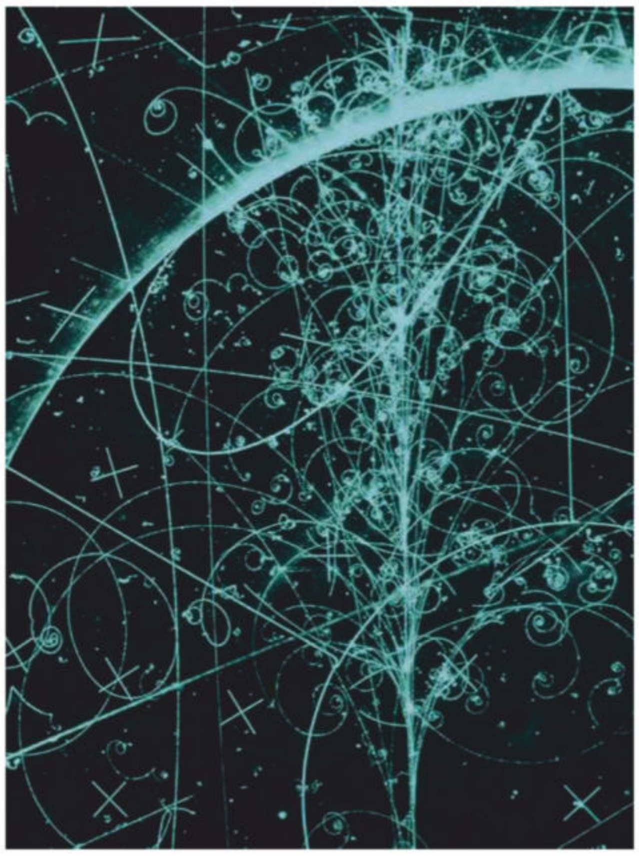
A RADICAL IDEA...

Zurich, Switzerland, December 1930. Wolfgang Pauli was having the worst year of his life. His mother had committed suicide two years earlier, causing him to turn his back on the Catholic Church. He had recently married a Berlin cabaret dancer but she had already moved in with her chemist boyfriend down the road. He had even appealed for help from the great psychoanalyst Carl Jung. But Pauli's main distraction from his personal distress was physics – and one physics problem in particular had captured his attention.

In the late 1920s, physicists were pulling their hair out over the puzzle of beta decay. In beta decay, an unstable, or 'radioactive' nucleus sheds its surplus energy by spitting out an electron. The peculiar thing is that the ejected electrons do not always have the same energy. Think how bonkers this is. In dropping from an

LEFT The main spectrometer at the KATRIN experiment. KATRIN aims to measure the mass of the neutrino, vital for understanding the Universe

BELOW As a neutrino enters the bubble chamber, it collides with an electron giving it enough energy to cause charged particles to travel in helical paths, seen here as curls branching off the neutrino's path



unstable state to more stable state, a nucleus sheds a well-defined amount of energy, exactly like a gun firing a bullet. But bullets are always ejected with the same energy. It is never the case that one bullet shoots out at high speed, the next at a lower speed, and the one after so slowly it merely dribbles out of the gun muzzle.

Pauli was in a good position to solve the puzzle of beta decay, despite his angst-ridden personal life. He was one of the architects of quantum theory, concocted in the mid-1920s to describe the counterintuitive world of the atom and its constituents. Famously, at the end of a lecture given by Einstein, he had stood up and told the audience: "What Professor Einstein said is not entirely stupid."

Pauli wrestled with the problem of beta decay for many months. And the solution he came up with was radical. Perhaps, in beta decay, the electron is not alone, and is instead emitted along with another particle. Think of the gun again. If the bullet emerges from the muzzle with a second projectile, then if the second projectile takes only a small amount of the total energy, the bullet will take the lion's share; if the second projectile takes most of the available energy, then the bullet might very well have so little energy it dribbles out of the gun muzzle. Could this be the solution to the beta decay puzzle? Could there really be a second particle out there?

For such a particle to have not shown up in any experiment, it would have to be elusive. Pauli predicted its properties: zero electric charge, zero mass and an ability to pass through matter without being stopped. Pauli imagined the particle penetrating a thickness of 10 centimetres of lead with no difficulty; later physicists would realise that a layer of lead many light-years thick would be necessary to stop such a particle. Pauli christened the hypothetical particle a 'neutron'. But, with the discovery of a chargeless counterpart of the proton in 1932 – the neutron – the Italian physicist Enrico Fermi would rename it the 'neutrino'.

The neutrino was, in Pauli's words, a "desperate remedy". "I have done a terrible thing," he said. "I have postulated a particle that cannot be detected." In fact, Pauli bet a case of champagne that nobody would ever manage to bag a neutrino. However, he had not counted on human ingenuity... **(Turn to p57)**

DISCOVERING THE NEUTRINO

Savannah River, South Carolina, 14 June 1956. Frederick Reines had spent much of the 1950s exploding nuclear bombs in the Pacific Ocean. One, with 700 times the destructive power of the Hiroshima bomb, had vaporised an entire island, creating a radioactive mushroom cloud 150 kilometres across and gouging a hole in the ocean floor more than two kilometres wide and as a deep as a 16-storey building. But Reines was sick to death of it. He persuaded the leader of the theoretical division at the bomb lab in Los Alamos, New Mexico, to give him time off from testing weapons to think about physics. For several months, he sat in a bare office staring at a blank piece of paper, asking himself the question: "What do you want to do with your life?"

Reines flew to a conference in Princeton, New Jersey, and the plane developed engine trouble, forcing a stopover in Kansas City. On the plane was another bomb scientist called Clyde Cowan, who Reines had met but never talked to properly. In Kansas City, the pair hit it off. When their conversation turned to fundamental physics, the question that came up was: "What is the hardest experiment in the world?" Both instantly agreed: detecting the neutrino. There and then, they decided to use their 'can do' attitude, developed during the bomb programme, to try and bag nature's most elusive particle.

Their first idea was to place a neutrino detector 50 metres from Ground Zero of a nuclear explosion. They had a 50-metre-deep vertical shaft dug at the Nevada bomb testing site. If, at the instant of detonation, the detector were dropped into the shaft, it would be in freefall and isolated from the shockwaves thundering through the ground. At the bottom of the shaft, the detector's fall would be cushioned by a thick bed of foam rubber and feathers. Reines and Cowan intended to retrieve the detector several days later when radiation levels were deemed low enough to risk a quick in-and-out foray.

Fortunately, it never came to this. Reines and Cowan decided to use a nuclear reactor rather than a bomb. Although a nuclear reactor was a source of neutrinos 1,000 times weaker than a nuclear bomb, it had the advantage that a detector might soak up neutrinos for months or even years, rather than the few seconds available at a bomb blast. Reines and Cowan eventually found an ideal reactor at the Savannah River Plant, a facility used to make the tritium and plutonium for nuclear bombs. As a tribute to the local cuisine of South Carolina, they even planned to shield their experiment from stray neutrons with sacks of black-eyed peas. Sadly, wet sawdust was easier and cheaper to obtain in the required quantities. It was at P Reactor at the Savannah River Plant that, on 14 June 1956, Reines and Cowan finally bagged neutrinos (strictly speaking, antineutrinos).

Their telegram to Wolfgang Pauli read: "We are happy to inform you that we have definitely detected neutrinos from fission fragments by observing the inverse beta decay of protons… Frederick Reines, Clyde Cowan."

The next day, Pauli sent a reply from ETH Zürich, the Swiss Federal Institute of Technology: "Frederick REINES, and Clyde COWAN, Box 1663, LOS ALAMOS, New Mexico. Thanks for the message. Everything comes to him who knows how to wait. Pauli."

ABOVE Nearly a mile beneath the Gran Sasso mountain and 60 miles outside of Rome, this stainless steel sphere is part of the neutrino detector used to detect geoneutrinos

BELOW The US flag hangs proudly on the P Reactor at Savannah River Site, used to detect the neutrino in 1956, one of the most significant experiments in modern physics

18+

WHAT IS
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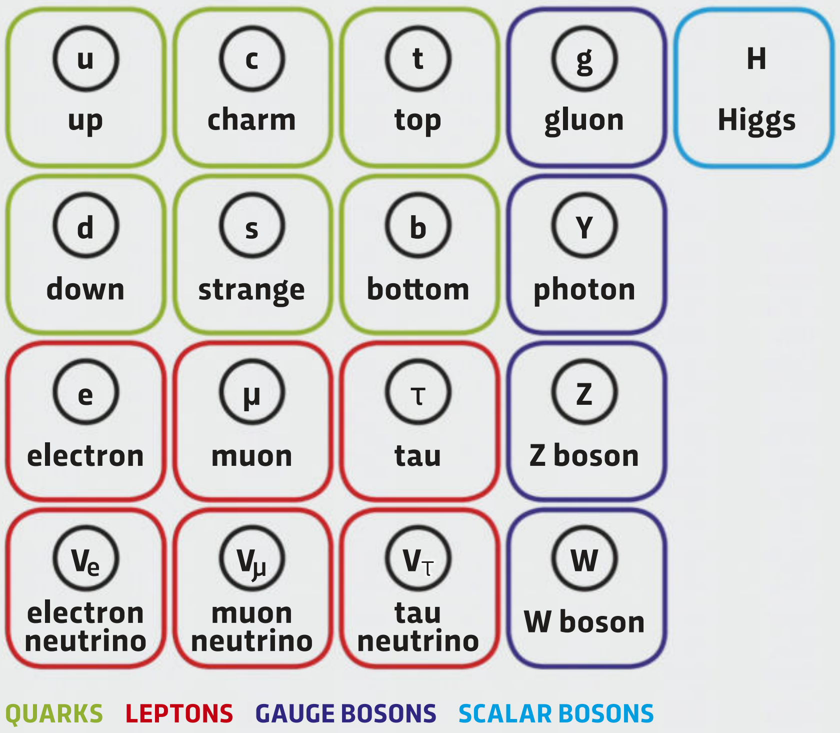
PAOLO LOMBARDO/INFN-MI, US DEPARTMENT OF ENERGY

STANDARD MODEL OF ELEMENTARY PARTICLES



u up	c charm	t top	g gluon	H Higgs
d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

QUARKS LEPTONS GAUGE BOSONS SCALAR BOSONS

These are the elementary particles, which together make up the Standard Model of particle physics. All of the atoms in the Universe are built using only the electrons and the 'up' and 'down' quarks. These interact with each other and stick together with the help of gluons and photons. Gluons transmit what is known as the 'strong force' that binds together quarks to make protons and neutrons, the building blocks of atomic nuclei. Photons transmit the electromagnetic force that acts between electrically charged particles, like electrons.

The other particles in the table are also important, but for less evident reasons. For example, around 60 billion electron neutrinos stream through every square centimetre of your body every second. These neutrinos are made inside the Sun, as a by-product of the process that fuses hydrogen into helium. The 'weak force' is responsible for this process of nuclear fusion and is transmitted by the W and Z particles.

The particles in the second and third columns of the Standard Model are like heavier copies of those in the first column. The existence of these heavier particles was crucial in governing the behaviour of the Universe shortly after the Big Bang.

is a different mix of all three masses. Imagine an animal that is 25 per cent cat, 25 per cent dog and 50 per cent giraffe. This conveys some idea of the weirdness of neutrinos. As each type flies through space, its individual mass components travel at different speeds, and consequentially the relative proportions of each mass state changes. This results in a neutrino 'oscillating' between an electron-, muon- and tau-neutrino.

Measurements of neutrino oscillations will provide estimates of the differences between masses of the three neutrinos. Importantly, KATRIN pins down an upper limit on one mass. Crucially, however, we still don't know the neutrino-mass hierarchy – whether electron-, muon- and tau-neutrinos get progressively more massive as do electrons, muons and taus.

Underdstanding neutrino oscillations and neutrino masses is vitally important. If the 'mixing' between neutrino mass states is big enough, it could indicate that nature permits a process that, in the jargon 'violates charge-parity symmetry'. This would make antineutrinos behave differently from neutrinos. By favouring the production of matter over antimatter, this could solve one of the outstanding puzzles of cosmology: why we live in a Universe of matter. "According to the Standard Model, all fundamental particle processes create equal quantities of matter and antimatter," says Uchida. "We therefore should not exist [because when matter and antimatter particles meet, they annihilate]!".

RETHINKING THE EARLY UNIVERSE

Neutrino oscillations may reveal the existence of a fourth, 'sterile' neutrino, interacting with matter so rarely it makes the other three flavours appear positively sociable. The total mass of all three (or more) types of neutrino has consequences for the Universe because neutrinos are the second most common subatomic particle, after photons. In the early Universe, their considerable gravity would have helped matter clump together to make the first galaxies. The more massive neutrinos are, the earlier they would have slowed down after the Big Bang and the clumpier our Universe should be. Consequently, knowing the masses of the neutrinos helps pin down the cosmological model that best describes our Universe. If astronomers' observations of clumpiness contradict that model, then it will be strong evidence of physics beyond the Standard Model.

by MARCUS CHOWN

Marcus is a science writer and journalist. His new book, The Magicians *(£12.99, Faber & Faber), tells the story of the prediction and discovery of the neutrino alongside many other stories.*

20 IDEAS YOU NEED TO KNOW ABOUT IN 2020

The year 2010 doesn't sound like it was that long ago. But a decade ago Tinder, Uber and Instagram didn't exist. No one wore wearables, nobody talked to their gadgets at home and the Tesla was just an idea. Back then, scientists were still looking for the Higgs Boson, Pluto was a mysterious blurry orb just out of sight and genetic editing was still just a theoretical concern, not a practical one. The next decade looks set to move even faster. So here's our tour to the science and tech to look out for this decade.

words by ROB BANINO, ANDY RIDGWAY, HAYLEY BENNETT

1

SYNTHETIC MEDIA UNDERMINES REALITY

The entertainment world will literally create the next generation of stars

You know about deepfake technology, where someone's face is switched into an existing video scene. But deepfakes are just the tip of the iceberg when it comes to synthetic media – a much wider phenomenon of super-realistic, artificially generated photos, text, sound and video that seems destined to shake our notions of what is actually 'real' over the next decade.

Take a look at the website below. Hit refresh a few times. None of the faces you see are real. Uncannily realistic, they are entirely synthetic – generated by generative adversarial networks, the same type of artificial intelligence behind many deepfakes. These false photos show just how far synthetic media has come in the past few years. Elsewhere, China's Xinhua state news agency has provided an insight into possible uses of synthetic media – computer-generated news anchors. While the results are a little clunky, it suggests a direction where things may be heading.

While such synthetic media has potential for an explosion in creativity, it also has the potential for harm, by providing purveyors of fake news and state-sponsored misinformation new, highly malleable channels of communication.

thispersondoesnotexist.com

2 THE CLOUD ROBOTICS REVOLUTION

A global network of machines talking and learning from one another (sound familiar?) could create robo-butlers

Until now, robots have carried their pretty feeble brains inside them. They've received instructions – such as rivet this, or carry that – and done it. Not only that, but they've worked in environments such as factories and warehouses specially designed or adapted for them. Cloud robotics promises something entirely new; robots with super-brains stored in the online cloud. The thinking is that these robots, with their intellectual clout, will be more flexible in the jobs they do and the places they can work, perhaps even speeding up their arrival in our homes.

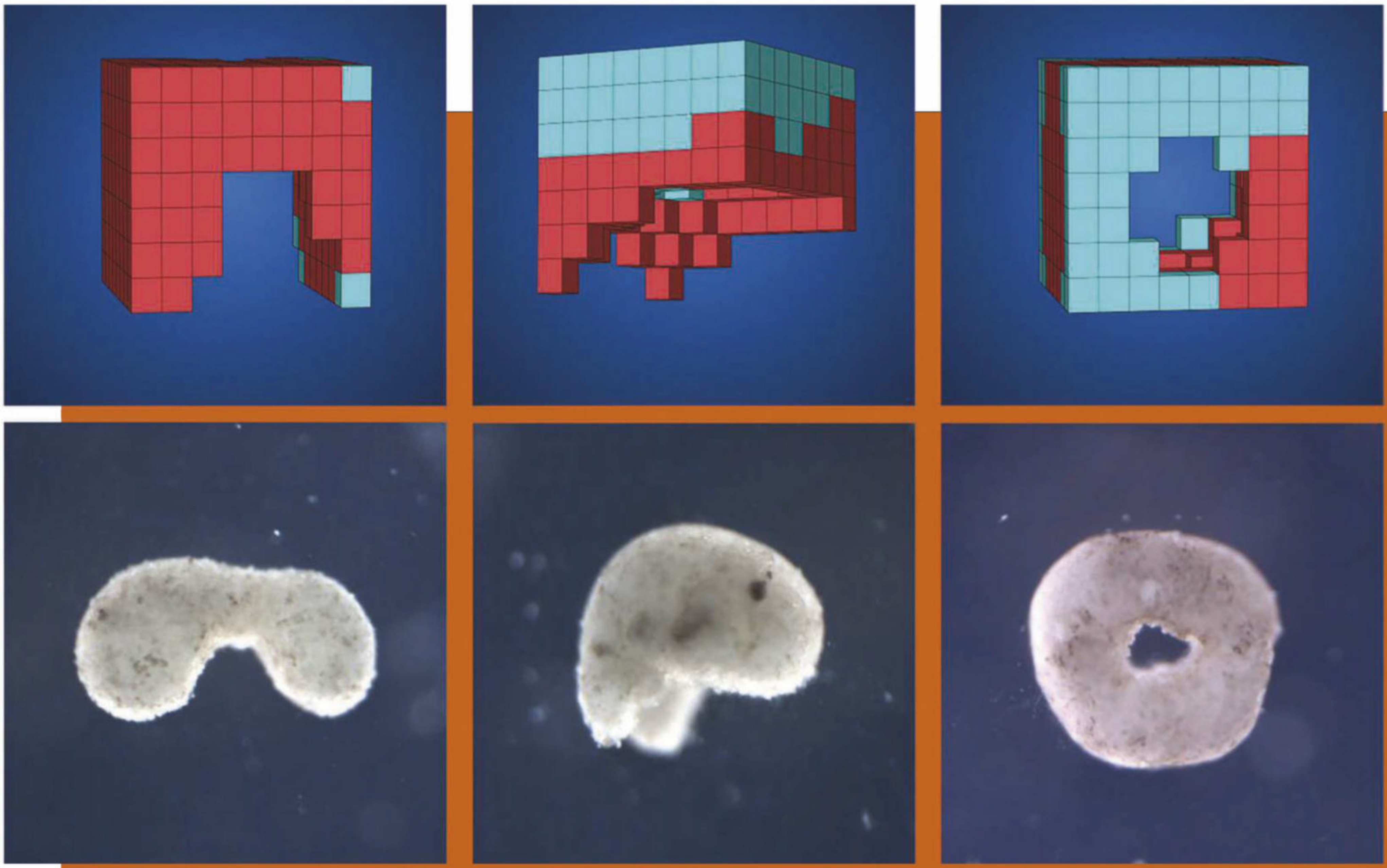
Google Cloud and Amazon Cloud both have robot brains that are learning and growing inside them. The dream behind cloud robotics is to create robots that can see, hear, comprehend natural language and understand the world around them.

One of the leading players in cloud robotics research is Robo Brain, a project led by researchers at Stanford and Cornell universities in the US. Funded by Google, Microsoft, government institutions and universities, the team are building a robot brain on the Amazon cloud, learning how to integrate different software systems and different sources of data.

Another one to watch is the Everyday Robot Project, by X, the 'moonshot factory' at Alphabet, Google's parent company. The project aims to develop robots intelligent enough to make sense of the places we live and work. They're making headway too – testing cloud robots in Alphabet offices in Northern California. So far, the tasks are simple, such as sorting the recycling (pretty slowly says X), but it's the shape of robots to come.

The Fetch Cloud Robotics Platform is a cloud-driven Autonomous Mobile Robot (AMR) solution that addresses material handling and data collection for warehouses

GETTY IMAGES



AI automatically designs candidate lifeforms in simulation (top row), then a cell-based construction toolkit is used to create the living systems

3

THE RISE OF LIVING MACHINES

Biological robots could start solving our problems

Synthetic biologists have been redesigning life for decades now, but so far they've mostly been messing about with single cells – a kind of souped-up version of genetic modification. In 2010, Craig Venter and his team created the first synthetic cell, based on a bug that infects goats. Four years later, one of the first products of the synthetic biology era hit the market, when the drug company Sanofi started selling malaria drugs made by re-engineered yeast cells.

Today, though, biologists are starting to find ways to organise single cells into collectives capable of performing simple tasks. They're tiny machines, or as biologist Josh Bongard at the University of Vermont refers to them, 'xenobots'. The idea is to 'piggyback' on the hard work of nature, which has been building tiny machines for billions of years.

Currently, Bongard's team makes its xenobots with ordinary skin and heart cells from frog embryos, producing machines based on designs etched out on a super-computer. Just by combining these two types of cells it designed machines capable of crawling across the bottom of a petri dish, pushing a small pellet around and even cooperating. "If you build a bunch of these xenobots and sprinkle the petri dish with pellets, in some cases they act like little sheepdogs and push these pellets into neat piles," Bongard says.

Their computer runs a simple evolutionary algorithm that initially generates random designs and rejects over 99% of them – selecting only those designs capable of performing the required task in a virtual version of a petri dish. As Bongard explains, the scientists still have to turn the finished designs into reality, layering and sculpting the cells by hand. This part of the process could eventually be automated, using 3D printing or techniques to manipulate cells using electrical fields.

You couldn't yet call these xenobots living organisms, though, as they don't, for example, eat or reproduce. Since they can't utilise food, they also 'die', or at least decompose, and quickly, meaning there's no obvious hazard to the environment or people. However, combining this approach with more traditional synthetic biology techniques could lead to the creation of new multicellular organisms capable of performing complex tasks. For example, they could act as biodegradable drug delivery machines, and if made from human cells, they would also be biocompatible, avoiding triggering adverse immune reactions. But that's not all. "In future work," says Bongard, "we're looking at adding additional cell types, maybe like nervous tissue, so these xenobots would be able to think."

4 SILICON VALLEY TRIES TO GO CARBON NEGATIVE

The tech world is hoping it can turn back the clock on climate change by removing carbon emissions

A rapid shift away from using fossil fuels is what's required if we're going to keep the average global temperature rise within the 1.5°C window needed to mitigate the worst effects of climate change. But that's not all we can do. Instead of trying to limit our carbon emissions, there is scope to actually remove them from the atmosphere. That's what Microsoft announced it would start doing, when the software giant kicked off 2020 by revealing its intention to be carbon negative by 2030. But that's not all; Microsoft also said that by 2050, it plans to "remove from the environment all the carbon the company has emitted since it was founded in 1975."

Achieving that goal will take more than simply switching to renewable energy sources, electrifying its fleet of vehicles and planting new forests. Hence, Microsoft is monitoring the development of negative emissions technologies that include bioenergy with carbon capture and storage (BECCS), and direct air capture (DAC).

BECCS uses trees and crops to capture carbon as they grow. The trees and plants are then burnt to generate electricity but the carbon emissions are captured and stored deep underground. DAC uses fans to draw air through filters that remove the carbon dioxide, which can then be stored underground or potentially even turned into a type of low-carbon synthetic fuel.

Both methods sound promising but have yet to reach a point where they are practical or affordable on a scale necessary for them to have a significant impact on climate change. Microsoft's hope, as well as those of everyone else looking to turn the tide of the climate crisis, is that these technologies, and others, will develop further over the years to come to a point that makes them viable.

5 PESTS DRIVEN OFF WITHOUT CRUELTY

Labs investigate gene drives to fend off invasive species like grey squirrels and cane toads

Another potential use for gene-editing is wiping out pests. Dubbed "gene drives", self-replicating edits based on CRISPR technology could ravage through entire populations. In lab trials, the newly-introduced DNA often makes one sex sterile, duplicating itself to infect both copies of an animal's chromosomes so that it's passed on to all its offspring. Some mosquitoes have developed resistance against gene drive mutations, but researchers believe they'll be able to pull off the technique as long as they target the right genes. For safety, scientists are designing 'override' drives capable of reversing the edits. In a 2018 paper , researchers from Edinburgh's Roslin Institute, which created the first cloned sheep ("Dolly"), suggested gene drives could deal humanely with the Australian cane toad problem. The toxic toads were introduced from Hawaii in 1935 and have killed almost anything that has tried to eat them ever since. The same scientists propose controlling grey squirrels with gene drives, in order to save the UK's native reds.

GETTY IMAGES X2, SAM KRIEGMAN/DOUGLAS BLACKISTON

6

MUSHROOMS WITH A VIEW

Space missions test growing buildings out of fungus

If we have to flee Earth to take up residence elsewhere in the galaxy, you know what we need to take with us? Mushrooms. Or rather, fungal spores. Not to feed us on the flight over there, but to grow our houses with.

That's the thinking behind NASA's myco-architecture project. The space agency is concocting a plan to grow buildings made out of fungi on Mars. According to astrobiologist Lynn Rothschild, who works on the project, it's a no-brainer when you consider the cost of launching a full-size building into space, versus some practically weightless life-forms that happen to be natural builders. "We want to take as little as possible with us and be able to use the resources there," she says.

Many fungi, like mushrooms, grow and spread using mycelia – networks of thread-like tendrils that form sturdy materials capable, with minimal encouragement, of growing to fill any container. On Earth, fungi-fabricated structures are already used to make packaging for wine bottles and as particle board-like materials, and Rothschild suggests they could even be used for growing refugee shelters.

On Mars, the organisms would need a little water to get started, which could come from melted ice, plus a food source. The researchers envisage them being deployed in large bags that would be inflated on landing to provide a container to fill. These bags would contain the food source in dried form and offer the added benefit of preventing contamination of the atmosphere with alien fungi. Once the structures were fully grown, a heating element would be activated, baking the mycelium network like bread to harden it.

If you're imagining organic-looking buildings with walls sprouting toadstools and orchids, though, think again. Rothschild's current materials are more "like wholewheat bread that's been left out", although she says they could be brightened up by adding colour pigments, through genetic modifications.

Rothschild already has a myco-made stool in her office, which took her students about two weeks to grow, and the team has plans for full-scale structures. But for future space missions, they'd like to send an advance party of robots to do the work for them. "When I travel, I want a hotel to go to," says Rothschild. "I don't want to arrive at an airport and they say 'we're going to build the hotel tonight' and so I think the ideal situation would be to send precursor missions where these things were erected."

NASA are exploring ideas that involve sending large 3D printers to Mars, that will use material sourced from Mars, but using fungal spores will significantly reduce the payload weight

7. DISEASES EDITED OUT OF OUR DNA

The gene-editing tool CRISPR could finally treat disease at the genetic level

The birth of the world's first gene-edited babies caused uproar in 2018. The twin girls whose genomes were tinkered with during IVF procedures had their DNA altered using the gene-editing technology CRISPR, to protect them from HIV. CRISPR uses a bacterial enzyme to target and cut specific DNA sequences. Chinese researcher, He Jiankui, who led the work, was sent to prison for disregarding safety guidelines and failing to obtain informed consent. But in ethically sound studies, CRISPR is poised to treat life-threatening conditions. Before the controversy, Chinese scientists injected CRISPR-edited immune cells into a patient to help them fight lung cancer. By 2018, two US trials using similar techniques in different kinds of cancer patients were up and running, with three patients reported to have received their edited immune cells back. Gene-editing is also being tested as a treatment for inherited blood disease sickle cell anaemia, an ongoing trial will collect and edit stem cells from patients' own blood.

8. PARALYSED PATIENTS WALK AGAIN

Paralysed patients lucky enough to be enrolled in clinical trials are already walking again thanks to rapidly advancing neurotechnology. In 2018, Swiss and UK scientists announced they had placed nerve signal-boosting implants into the spines of three men paralysed in road and sporting accidents. All are now able to walk a short distance.

And just last year, in a truly sci-fi-style demonstration, researchers at the Grenoble University Hospital in France used an exoskeleton to give a 28-year-old man back the use of his lower limbs after falling and breaking his neck. The man uses two 64-electrode brain implants to control the robo-suit.

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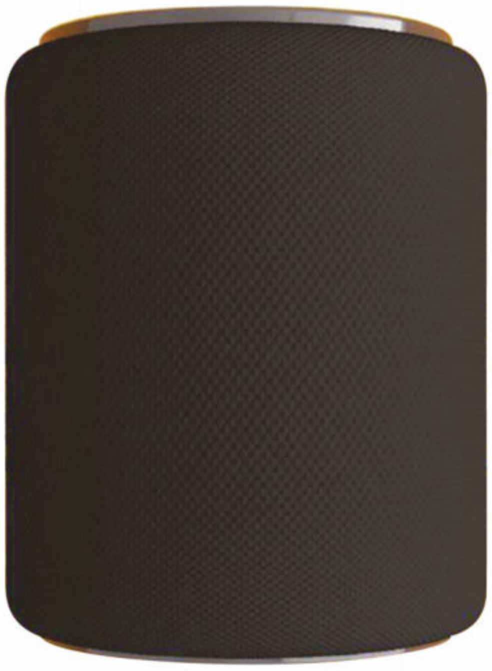

9. NATURAL LANGUAGE GADGETS GET WEIRD

Speech-enabled tech, like Alexa, Siri or Google Voice, will start to shape our own speech

The fantasy of controlling our devices through speech is becoming a reality, even though they can only handle simple commands or enquiries and their speech patterns sound robotic. The next step is getting them to understand and respond in natural language – the sort of conversational exchanges humans use. Google seemed to have made progress when it unveiled its Duplex system in 2018. An add-on for its Assistant app, Duplex employs more sophisticated types of AI to understand and use natural language to book restaurant tables and hair appointments, or ask about a business's opening hours. If the booking couldn't be made online, Assistant would handover to Duplex, which would call the restaurant and speak to the staff to book you in. According to reports, people that spoke to Duplex said they didn't realise they were talking to a machine. The trouble was, Duplex often ran into complications and needed someone to step in. Despite this setback, Google and other developers are still working on ways to bring natural language to our devices.

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10

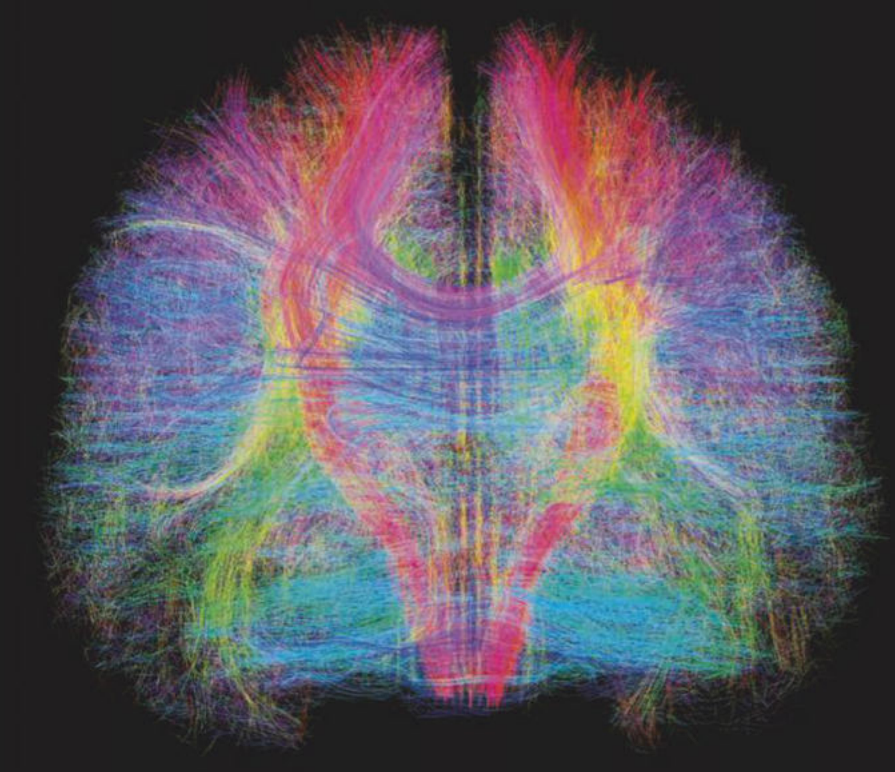
A HUMAN BRAIN MAP

The plan to write a set of instructions for the human brain takes shape

Understanding the human brain is a monumental task, but that hasn't stopped neuroscience stepping up to meet the challenge. There's the Human Brain Project, one of the largest ever EU-funded projects, the $5 billion BRAIN Initiative in the US, and the more recently announced China Brain Project.

One of the aims of the US initiative, launched in 2013, is to map all the neurons in the brain as well as their connections. Starting with the mouse brain, the view is to move towards the same goal in humans. It could "help us crack the code the brain uses to drive behaviour," says Joshua Gordon, one of the National Institutes of Health (NIH) project directors. But he admits it won't happen overnight. Take the Human Genome Project for example, a simple map won't provide all the answers and it may take many years to figure out how the physical features of the brain relate to memories, thoughts, actions and emotions.

For a start, the brain's 'code' can't be written



in a sequence of letters. According to Gordon, the first step is building a 'parts list' composed of different types of neurons and then mapping each of those parts in physical space. Currently, the parts list for mice is well underway, whilst the human equivalent could take another five to ten years. But understanding how these parts produce behaviour is trickier still. "Each of those parts also then has a constellation of functions," Gordon says. Eventually, there should be enough detail in the map to explain how neurons in certain brain circuits function at a molecular level, to produce specific behaviours.

The technologies being developed along the way will have a wider impact on neuroscience too, including research into a broad spectrum of brain disorders from epilepsy to Parkinson's. Rapid single-cell sequencing now allows scientists to quickly gather data from hundreds of thousands of individual neurons, highlighting the DNA that is switched on in each one. Meanwhile, imaging tools for studying neurons in exquisite detail and tracking their activities in real-time are advancing.

White matter fibres of the human brain

11. DEEPFAKE WARFARE

An arms race will pit AIs against each other to discover what's real and what's not

Deepfake videos have exploded online over the past two years. It's where Artificial intelligence (AI) is used to swap one person's image in a photo or video, for another's. Deeptrace, a company set up to combat this, says in just the eight months between April and December 2019, deepfakes have rocketed by 70% to 17,000.

Most deepfakes, about 96%, are pornography. Here, a celebrity's face replaces the original. In its 2019 report, *The State of Deepfakes*, Deeptrace says the top four dedicated deepfake porn sites generated 134,364,438 views.

As recently as five years ago, realistic video manipulation required expensive software and a lot of skill, so it was primarily the preserve of film studios. Now freely-available AI algorithms, that have learned to create highly-realistic fakes, can do all the technical work. All anyone needs is a laptop with a graphics processing unit (GPU).

The AI behind the fakes has been getting more sophisticated too. "The technology is really much better than last year," says Associate Professor Luisa Verdoliva, part of the Image Processing Research Group at the University of Naples in Italy. "If you watch YouTube deepfake videos from this year compared to last year, they are much better."

Now there are huge efforts within universities and business start-ups to combat deepfakes by perfecting AI-based detection systems and turning AI on itself. In September 2019, Facebook, Microsoft, the University of Oxford and several other universities teamed up to launch the Deepfake Detection Challenge with the aim of supercharging research. They pooled together a huge resource of deepfake videos for researchers to pit their detection systems against. Facebook even stumped up $10 million for awards and prizes.

Verdoliva is part of the challenge's advisory panel and is doing her own detection research. Her approach is to use AI to spot tell-tale signs – imperceptible to the human eye – that images have been meddled with. Every camera, including smartphones, leaves invisible patterns in the pixels when it processes a photo. Different models leave different patterns. "If a photo is manipulated using deep learning, the image doesn't share these characteristics," says Verdoliva. So, when these invisible markings have vanished, chances are it's a deepfake.

Other researchers are using different detection techniques and while many of them can detect deepfakes generated in a similar way to the ones in their training data, the real challenge is to develop a stealthy detection system that can spot deepfakes created using entirely different techniques.

The extent to which deepfakes will infiltrate our lives in the next few years will depend on how this AI arms race plays out. Right now, the detectors are playing catch-up.

This groundbreaking mind-controlled exoskeleton enabled Thibault to move all four of his paralysed limbs

12

BRAIN-MACHINE INTERFACES AND HUMAN AUGMENTATION

Exoskeletons will help the paralysed walk again and keep factory workers safe

Part of technology's promise is that it will enable us to exceed our natural capabilities. One of the areas where that promise is most apparent is brain-machine interfaces (BMIs), devices, implanted into your brain, that detect and decode neural signals to control computers or machinery by thought. Perhaps the best example of BMIs' potential came in October 2019 when Thibault, a paralysed Frenchman, used one to control an exoskeleton that enabled him to walk. What's currently holding BMIs back, however, is the number of electrodes that can be safely implanted to detect brain activity and that, being metal, the electrodes can damage brain tissue and will eventually corrode and stop working.

But last July, tech entrepreneur Elon Musk announced his company, Neuralink, could provide a solution. Not only does the Neuralink BMI claim to use more electrodes, they're carried on flexible polymer 'threads' that are less likely to cause damage or corrode. But it's difficult to know for sure how realistic these claims are, as the company has remained tight-lipped about the technology. Furthermore, it's yet to be trialled in humans.

Even without BMIs, exoskeletons are already being used to augment human capabilities, particularly for people whose capabilities might be limited as a result of illness or injury. At Hobbs Rehabilitation in Winchester, specialist physiotherapist Louis Martinelli uses an exoskeleton that straps on to a patient's back, hips, legs and feet to help them stand and step. "If the patient has had a really severe spinal cord injury, this is the only way to get them up and stepping sufficiently across the room," he says. "It's been shown to be really beneficial, particularly for blood pressure management, reducing the risk of vascular diseases, and bladder and bowel function."

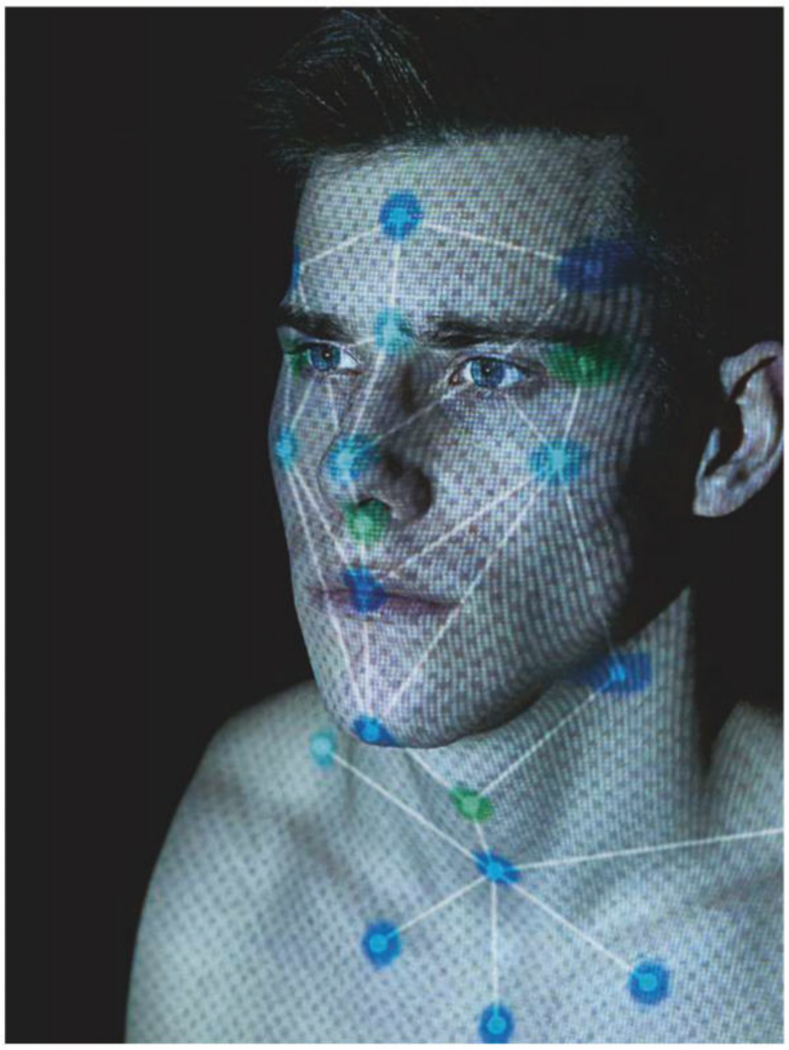
With the exoskeleton, only one to two physiotherapists are needed to assist the patient rather than a team of four or more. But it also allows the patient to achieve a lot more – taking several hundred steps during a session instead of the 10-20 with conventional therapy. There are potential applications elsewhere – upper body exoskeletons are being trialled in a US Ford manufacturing plant to help people carry heavy car parts.

But as useful as lower-body exoskeletons are, they're unlikely to replace wheelchairs anytime soon. That's partly because they struggle with uneven surfaces and can't match walking speed, but also because they're so much more expensive. Wheelchair prices start in the region of £150, whereas an exoskeleton can set you back anywhere between £90,000-£125,000. This is why Martinelli would like to see the technology get a little simpler in the years to come. "What I'd like to see is the availability of these pieces of equipment increase because they're very expensive. For individuals to get access to an exoskeleton is really difficult, maybe a simpler version that was half the price would allow more centres or more places to have them."

13. EMOTION-TRACKING MACHINES

Amid ethical concerns, scientists will strive to help AI read feelings

Emotion AI aims to peer into our innermost feelings - and the tech is already here. It's being utilised by marketing firms to get extra insight into job candidates. Computer vision identifies facial expressions and machine learning predicts the underlying emotions. Progress is challenging, though, reading someone's emotions is *really* hard. Professor Aleix Martinez, who was involved in the research, sums it up neatly, "not everyone who smiles is happy, and not everyone who is happy smiles." He is investigating whether emotional AI can measure intent - something central to many criminal cases. "The implications are enormous," he says.



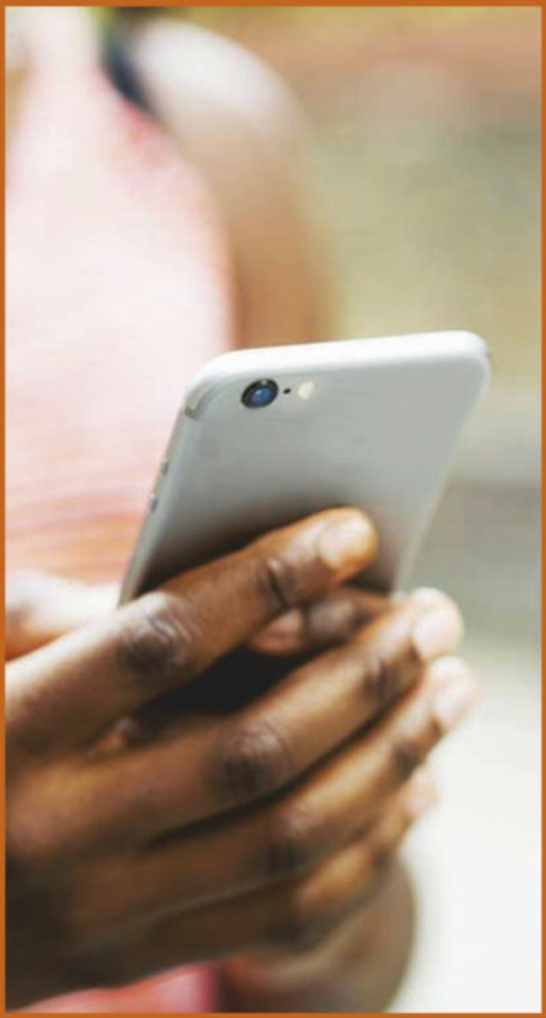
GETTY IMAGES X3

14. MAKING IT TO THE MOON AND MARS

Will we see astronauts set foot on the Moon in the next decade? Probably. What about Mars? Definitely not. But if NASA's plans come off, astronauts will be visiting the Red Planet by the 2030s. There is no doubting NASA's aspirations to plant astronaut feet on Mars. In one of its reports, *NASA's Journey to Mars*, they explain that the mission would represent "the next tangible frontier for expanding the human presence." The plan is to use the Moon and a small space station in orbit around the Moon, Gateway, as a stepping stone, allowing the space agency to develop capabilities that will help with the 34-million-mile journey to the Red Planet.
An independent report into NASA's Martian ambitions lays out a timetable that includes astronauts setting foot on the Moon by 2028, and a mission to orbit Mars less than a decade later, by 2037.

15. AI PSYCHIATRY

Social and health care systems are under pressure wherever you are in the world. As a consequence, doctors are becoming increasingly interested in how they can use smartphones to diagnose and monitor patients. Of course a smartphone can't replace a doctor, but given these devices are with us at almost every moment of the day and can track our every action, it would be remiss to use this ability for good. Several trials are already under way. MindLAMP can compare a battery of psychological tests with health tracking apps to keep an eye on your wellbeing and mental acuity. The screenome project wants to establish how the way you use your phone affects your mental health, while an app called Mindstrong says it can diagnose depression just by how you swipe and scroll around your phone.



16. PRIVACY MATTERS

After spending much of the last decade handing our data over to the likes of Apple, Facebook and Google via our smartphones, social media and searches, it seems as though people around the world, and the governments that represent them, are wising up to the risks of these corporations knowing so much about us. The next 10 years looks to be no different, only now we can add fingerprints, genetic profiles and face scans to the list of information we hand over. With the number of data breaches – companies failing to keep the data they hold on us secure – climbing every year, it's only a matter of time before governments step in, or as with the case of Apple, tech companies start selling us back the idea of personal privacy itself.

---

17. UBIQUITOUS INTERNET

Between 5G networks, and internet beamed down to us from Elon Musk's StarLink satellites, mobile internet will get a lot faster and a lot more evenly spread over the next decade. These new networks will empower entirely new fields of tech, from autonomous cars, drone air traffic control to peer-to-peer virtual reality. But it isn't without it's drawbacks. SpaceX is planning to launch 12,000 satellites over the next few years to create its StarLink constellation, with thousands more being deployed by other companies. More satellites mean more chances of collisions and more space debris as a result. The satellites have also been shown to interfere with astronomical observations and weather forecasting.

Earthscrapers could help provide living, office and recreational space for ever-increasing urban populations

18

UNDERGROUND CITIES

As populations move away from rural areas, urban planners look beneath their feet for answers

With space in cities so limited, often the only option for those who can afford to expand their property is to go underground. Luxury basements are already a feature beneath many homes in London, but with urban populations set to continue growing, subterranean developments are beginning to appear on a much larger scale.

One idea, still at the concept stage, is the 'Earthscraper' proposed for Mexico City. This 65-storey inverted pyramid has been suggested as a way to provide office, retail and residential space without having to demolish the city's historic buildings or breach its 8-storey height restriction.

Many questions remain as to the feasibility of such a project, however, such as how you provide light, remove waste and protect people from fire or floods. Some of these questions have potentially been answered with the construction of the Intercontinental Shanghai Wonderland hotel in China. This 336-room luxury resort was built into the rock face of an 88m-deep, disused quarry that opened for business in November 2018.

The island city-state of Singapore is also exploring its underground options. Not only are its Jurong Rock Caverns in the process of being turned into a subterranean storage facility for the nation's oil reserves, but there are also plans to build an 'Underground Science City' for 4,200 scientists to carry out research and development.

In New York, the Lowline Project is turning an abandoned subway station into a park. Expected to open in 2021, it uses a system of above-ground light-collection dishes to funnel enough light into the underground space to grow plants, trees and grass.

19

THE SEARCH FOR EXTRA-TERRESTRIAL LIFE

The European Space Agency's mission to Jupiter and its moons, JUICE, could be our best bet of finding alien life in our Solar System

If all goes according to plan, in May 2022 the European Space Agency will launch the first large-class mission of its Cosmic Vision Programme. The JUpiter ICy moons Explorer (or JUICE) will slingshot around Earth, Venus and Mars, picking up the speed it needs to propel it out to Jupiter.

JUICE is expected to arrive at the gas giant in 2029, where it will begin possibly the most detailed study of the planet to date.

"There are two goals," explains Dr Giuseppe Sarri, the JUICE project manager. "One is to study Jupiter as a system. Jupiter is a gas giant with over 70 moons, and for our understanding of the formation of the Solar System, studying [what amounts to] a mini solar system is scientifically useful. We'll study the atmosphere, magnetosphere and satellite system. The second goal is to explore the three icy moons, Callisto, Ganymede and Europa. Because on those moons there could be conditions that can sustain life, either in the past, present or maybe in the future."

It's important to note that JUICE won't be searching for signs of life on these moons, just the appropriate conditions to support it. In other words, to confirm the presence of salty, liquid water below the surface ice. "It's a little bit like below Antarctica. In the water below the ice there are very primitive forms of life so conditions could be similar to what we have below our poles," says Dr Sarri. "If there's a chance to have life in our Solar System, Europa and Ganymede are the places. Unfortunately JUICE won't be able to see the life but it'll take the first step in looking for it."

JUICE may also shed light on the mystery of rings. "It looks as if all the giant planets have rings," Dr Sarri explains. "In the past, astronomers only saw Saturn's rings but then rings were found at Uranus, Jupiter and Neptune. Understanding the dynamic of rings will help us understand the formation of these planets."

SAMSUNG, ALAMY, FOREST STEARNS/GOOGLE

20. QUANTUM COMPUTERS ARE THE NEW SUPERCOMPUTER

Complex data, like weather patterns or climate changes, will be crunched though in the fraction of the time

Dreams of exploiting the bizarre realm of quantum mechanics to create super-powerful computers have been around since the 1980s. But in 2019 something happened that made lots of people sit up and take quantum computers seriously. Google's quantum computer, Sycamore, solved a problem that would take conventional computers much, *much* longer. In doing so, Sycamore had achieved 'quantum supremacy' for the first time – doing something beyond conventional capabilities.

The task Sycamore completed, verifying that a set of numbers were randomly distributed, took it 200 seconds. Google claims it would have taken IBM's Summit, the most powerful conventional supercomputer, 10,000 years. IBM begs to differ, saying it would only take Summit 2.5 days.

Regardless, this landmark event has given the quantum computer research community a shot in the arm. A blog post by Sycamore's developers (**bit.ly/quantum_supremacy**) gives a sense of this. "We see a path clearly now, and we're eager to move ahead."

But don't expect to be using a quantum computer at home. It's more likely to be running simulations in chemistry and physics, performing complex tasks such as modelling interactions between molecules and in doing so, speeding up the development of new drugs, catalysts and materials. In the longer term, quantum computers promise rapid advances in everything from weather forecasting to AI.

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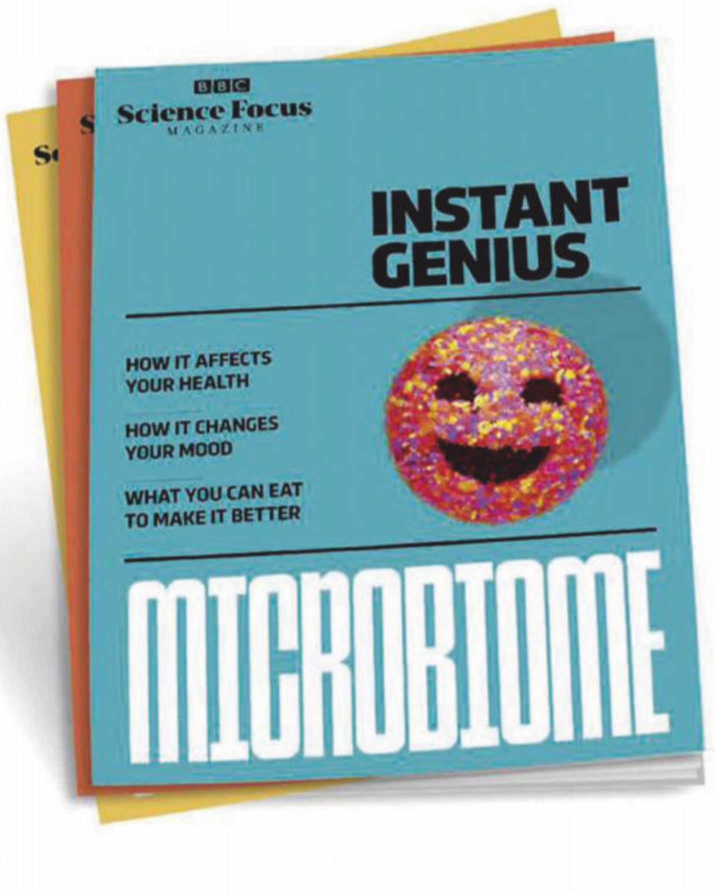
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ALOM SHAHA Science teacher, filmmaker, author

PROF ALICE GREGORY Psychologist, sleep expert

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DR HELEN PILCHER Biologist, science writer

PROF ROBERT MATTHEWS Physicist, science writer

JACK STECHER, DALLAS, TEXAS

WOULD A MODERN COMPUTER BE ABLE TO DERIVE THE EQUATION E=mc²?

Artificial intelligence (AI) algorithms have had some success in learning the laws of physics. In 2009, researchers at Cornell University fed data from a swinging pendulum to their AI, and it managed to learn laws such as the conservation of momentum and Newton's second law of motion. In 2018, researchers at MIT went further, showing their 'AI physicist' a bouncing ball in various simulated worlds, which allowed it to derive the laws for each simulation. Like a scientist, the algorithm could even combine individual laws to make unified theories. To discover $E=mc^2$, we would need to show an AI object behaving according to Special Relativity. For example, we could create a simulated world in which the mass of an object appears to increase with speed. Let an AI loose in this world and it may well figure out Einstein's famous equation linking mass and energy. ***LV***

Hubo Lab
KAIST

ALAMY

BILLY WILSON, DEAL, KENT

IS THERE ANY HOPE OF CURING DIABETES?

Diabetes is actually several medical conditions with one thing in common: they all lead to unhealthy levels of glucose in the blood. While the human body needs quick access to sugar for energy, excessive levels increase the risk of premature death from heart disease, stroke and kidney failure.

Normally, blood sugar levels are controlled by the pancreas through the release of insulin, a hormone that helps cells absorb blood sugar. But this can go wrong in several ways, reflected in the different forms of diabetes.

In the UK, around 10 per cent of cases are so-called 'type 1' diabetes, caused by loss of the insulin-producing cells in the pancreas. For unknown reasons, these cells are attacked by the body's immune system, so patients need regular doses of insulin, usually by injection. But the most common type, at around 90 per cent, is 'type 2' diabetes, where cells no longer fully respond to insulin. This 'insulin resistance' leaves excess sugar in the blood, triggering demand for yet more insulin, leading to damage to the pancreas. Type 2 diabetes is often linked to diets rich in carbs and sugar, and sedentary lifestyles.

While there's no cure for either type, patients with severe type 1 can be offered a pancreas transplant, which typically works for around five years. There are also cases of patients becoming disease-free for a while, with their pancreas mysteriously regaining its ability to produce insulin. Whether this can be triggered by drugs is currently a focus of research. Intriguingly, a 2018 study at the University of Alabama at Birmingham, US, found that verapamil, a drug used to control blood pressure, can help type 1 diabetics maintain insulin production, but the research is still at an early stage. For those with type 2 diabetes, changing to a healthier diet, losing weight and taking more exercise can often prove effective in controlling symptoms. ***RM***

TAMSIN NICHOLSON, WARWICKSHIRE

WHY ARE SOME PEOPLE MORE SQUEAMISH THAN OTHERS?

Psychologists call squeamishness 'disgust sensitivity' or 'disgust proneness'. Disgust is an evolved emotional reaction that prompts us to avoid potentially contaminating material, such as blood, pus or faeces. This has obvious survival advantages, helping us to avoid infectious diseases and toxic food, but an overly sensitive disgust response can have drawbacks – making us less likely to try new foods, for instance, or board a crowded train. The survival value of different levels of squeamishness will have varied depending on the circumstances our ancestors found themselves in, and variability in the emotion has been passed down through the generations. Our disgust sensitivity is also influenced by early social learning, such as from our parents' disgust reactions, and by cultural customs around hygiene and purity. ***CJ***

DILEEP BAGNALL, LANCASHIRE

IS THE STRAIGHT LINE A HUMAN INVENTION?

You could argue that there's no such thing as a straight line, because everything – if you zoom in close enough – has irregularities. Even a beam of laser light is slightly curved, as light is bent by the Earth's gravitational field.

But if we relax our definition to 'something that looks straight to the human eye', then we can find plenty of straight lines in nature – rock strata, tree trunks, the edges of crystals, strands of spider silk.

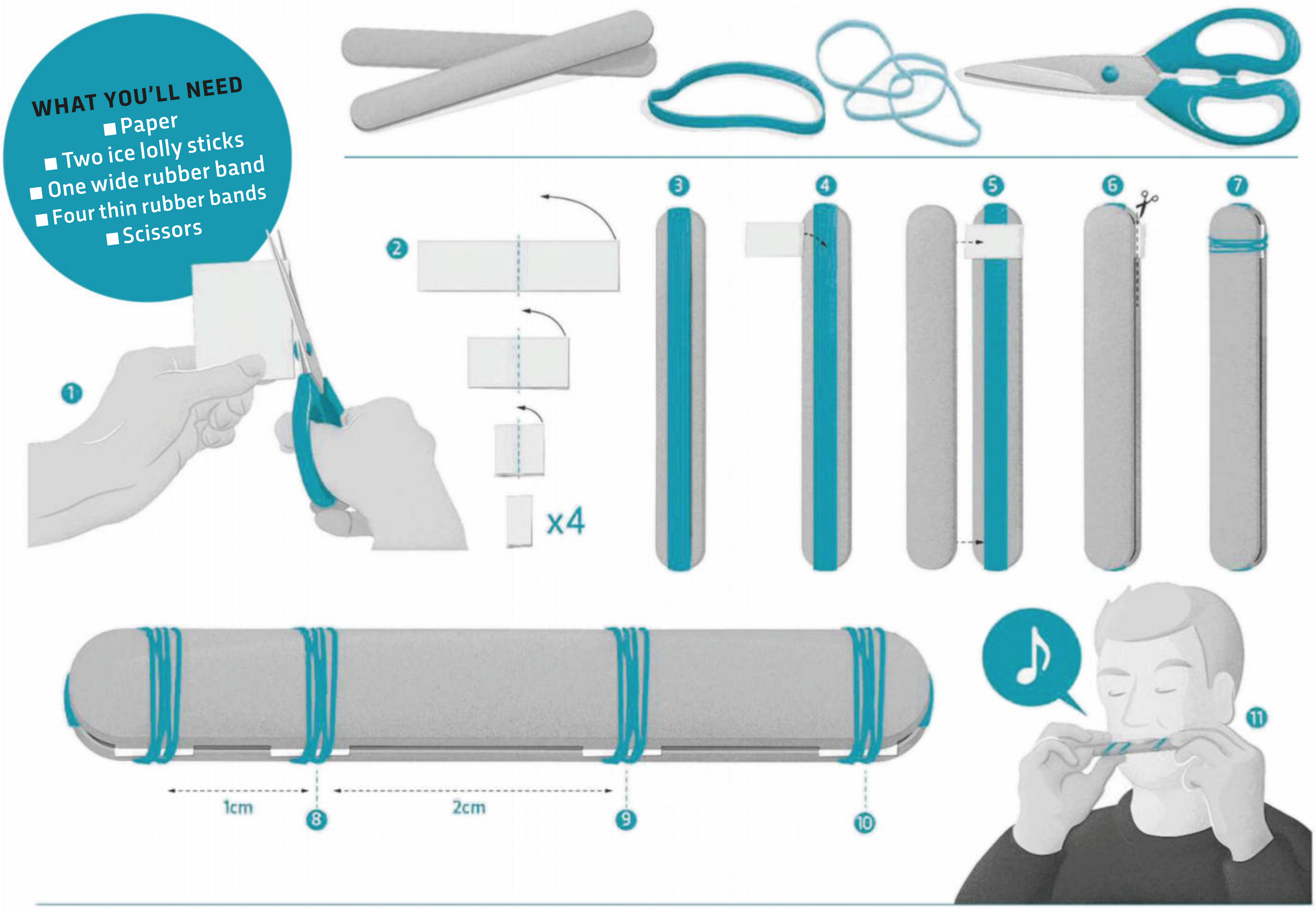
The reason we like straight lines is because of a fundamental property of the Universe – the shortest distance between two points is a straight line. Nature also follows this principle. Spiders, for example, make their webs by stretching silk strands across the shortest path.

It's true that curved lines are common in nature, but many of these are just an extension of this principle into three dimensions. The smallest surface area to enclose a volume is a sphere. So the bonds between water molecules pull raindrops into a sphere, and cells have rounded shapes to reduce the amount of cell membrane they need. *LV*

DIY SCIENCE

RUBBER BAND HARMONICA

We'd love to see videos of your harmonicas in action. Send them to us on Facebook or Twitter (**@sciencefocus**) and we'll share our favourites!



WHAT YOU'LL NEED

- Paper
- Two ice lolly sticks
- One wide rubber band
- Four thin rubber bands
- Scissors

WHAT TO DO

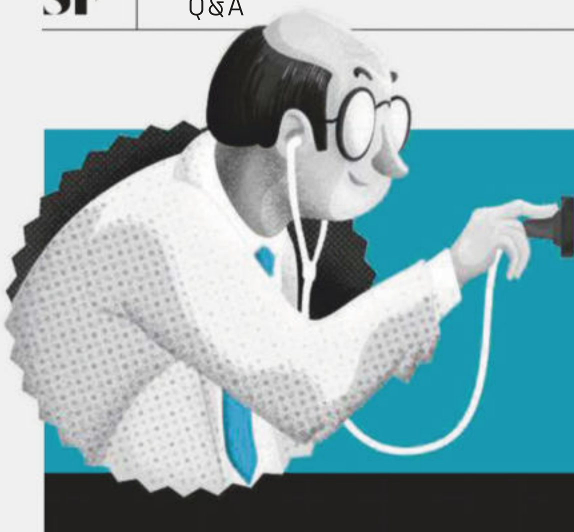
1. Cut out four paper rectangles, each roughly 4cm x 1cm.
2. Fold each piece of paper in half down its length three times to give four folded pieces of paper, each roughly 0.5cm x 1cm.
3. Stretch the wide rubber band around the length of one of the lolly sticks.
4. Place one folded piece of paper on top of the rubber band at one end of the stick.
5. Put the second stick on top so that the piece of paper is sandwiched between the sticks.
6. Cut off any paper sticking out from between the sticks.
7. Wrap a thin elastic band around the paper and sticks so that the paper is held firmly in place.
8. Place a second piece of paper between the sticks, about 1cm along from the first piece of paper. Again, cut off any paper sticking out, and secure the paper in place with an elastic band.
9. Repeat with a third piece of paper placed about 2cm further along.
10. Repeat with a final piece of paper placed right at the other end of the sticks.
11. Hold the harmonica so that the rubber band is around the bottom stick and blow through the gaps between the paper dividers. You should get three different notes!

WHAT'S HAPPENING

Blowing into the harmonica makes the wide rubber band vibrate, causing the air particles around it to vibrate at the same frequency (you can also feel the vibrations with your fingertips). These vibrations pass from air molecule to air molecule, producing a wave that travels away from the harmonica. When this wave reaches your ears, you detect it as sound.

The harmonica's paper dividers separate the rubber band into three different lengths. Blowing through the 'holes' between the dividers produces different notes because the different lengths of rubber vibrate at different frequencies. The frequency at which a rubber band vibrates is proportional to how tightly it is stretched, and inversely proportional to how long it is and how heavy it is. This means that shorter lengths of rubber vibrate at a higher frequency, producing a higher pitched note. Blowing harder doesn't change the pitch of the notes, but should make them louder. ***AS***

GETTY IMAGES X2 ILLUSTRATION: DAN BRIGHT



DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I'D LOVE TO TREAT MYSELF TO A GEL MANICURE, BUT ARE THEY BAD FOR ME?

Gel polish contains small molecules called monomers. When you put your hand under the ultraviolet (UV) nail lamp, the UV radiation triggers a chemical reaction that causes the monomers to link together to form long polymer chains, setting the gel. The result is a tough, flexible nail polish.

In 2009, US researchers sparked concern with an article describing how two nail bar regulars had developed skin cancer on the backs of their hands. However, the researchers weren't able to make any strong conclusions about whether the UV nail lamps were responsible, and a separate 2018 review of the literature concluded that the cancer risk from nail lamps is low. Nevertheless, the authors of the review recommend using fingerless gloves or sunscreen to protect the hands while under the lamp.

Finally, the nail filing that occurs before the polish, and the soaking in acetone to remove gel nails, can make nails more brittle and likely to split. So treat yourself, but it might be worth planning in some gel-free periods, and protecting your hands. ***ED***

I'M HUNGRY, THE SHOPS ARE SHUT AND ALL I HAVE IN MY CUPBOARD IS DOG FOOD. WOULD IT BE SAFE TO EAT?

Dog food is nutritionally balanced for the canine metabolism, so it has more fat and less protein than we need, and it's also enriched with vitamin A, which can be harmful in high doses to humans in the long term. None of this should be a problem if you're only eating one tin. More of a risk is that – although most tinned pet food is made from ingredients that are left over from human food manufacture – stringent human food safety regulations don't always apply, and there have been incidents of contaminated pet food. So it's probably best to find an all-night café! ***LV***

I HATE PUBLIC SPEAKING. IS 'IMAGINE THE AUDIENCE NAKED' REALLY THE BEST ADVICE FOR OVERCOMING NERVES?

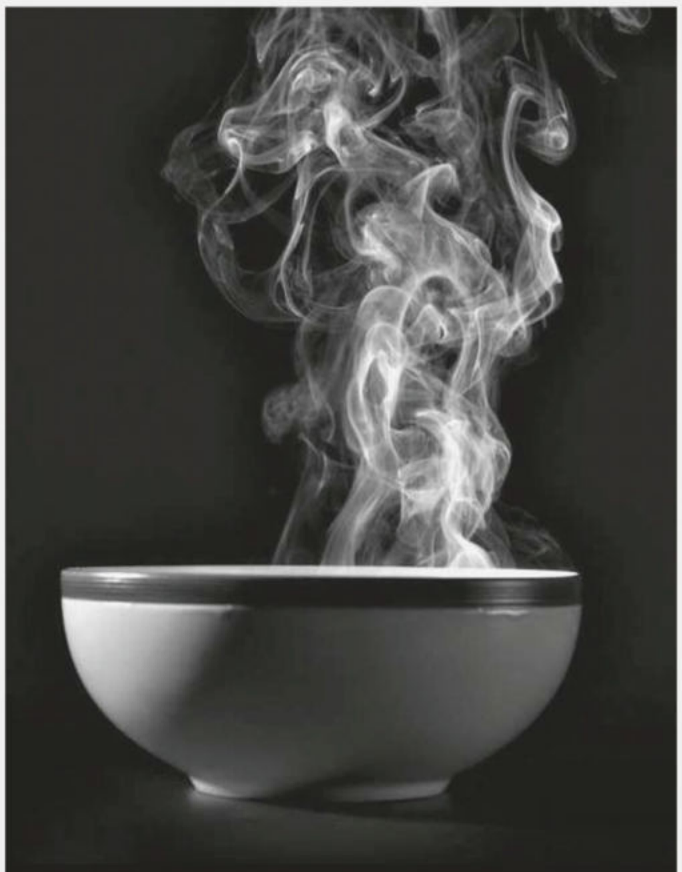
This advice has been around for years. The idea is that it will make your audience seem less threatening and so reduce your nerves. However, public speaking experts say it's an unwise technique – after all, the key to being an effective presenter is to respect and engage your audience, not to see them as the enemy or to mock them (if you have a vivid imagination, the strategy could also be overly distracting!).

To calm your nerves, you're better off using a technique known as 'cognitive reappraisal'. Research at Harvard Business School has shown that speakers who deliberately reevaluate their nerves as excitement rather than anxiety (for example, by saying "I am excited" out loud) perform better than those who try to calm themselves down. More generally, one of the best things you can do is to prepare thoroughly. Make sure your speech does not overrun, practise in front of friends and family, and visit the venue ahead of time if you can. Finally, create some 'if-then' plans to help you cope, such as "if I begin to feel overwhelmed, then I will take a deep breath and refocus". ***CJ***

ADAM KING, HUDDERSFIELD

WHY ARE SUNSPOTS BLACK?

Sunspots are areas of the Sun's photosphere (the visible surface) that are significantly cooler than the surrounding regions. Although the exact details of sunspot formation are not fully understood, they are coincident with areas of increased magnetic field. These intense magnetic fields appear to suppress the release of heat into the photosphere, thus making sunspots cooler than their surroundings by a couple of thousand degrees Celsius. This means that sunspots are only about a third as bright as the surrounding photosphere, and it's this contrast in brightness that makes them appear dark, even black. If you could pluck a sunspot from the Sun and put it in the night sky, it would actually be about as bright as the surface of the Moon as seen from Earth. ***AGu***



KEVIN WARD, STROUD

IS HOT FOOD MORE FILLING THAN COLD FOOD?

Hot food does tend to make you feel full for longer, and this is because it increases the time it takes for your appetite to return. Freshly cooked food has more flavour because of the volatile organic compounds that are released, and this extra stimulation makes the food feel more satisfying than the same nutrients eaten cold. It's also much harder to bolt down hot food, and eating slowly signals to your brain that you are consuming a substantial meal – and so your brain suppresses your appetite for longer once you've finished your meal. ***LV***

£3.9bn

The estimated global cost of damage to crops by diamondback moths each year. To try and combat this, US scientists are trialling a release of male moths that have been genetically modified to ensure their female offspring die soon after hatching.

CATHERINE MURPHY, VIA EMAIL

WHY ARE SPHYNX CATS HAIRLESS?

It's due to a mutation in the gene that is responsible for providing hairs with their keratin protein as they emerge from the follicle. The hair is formed, but it has a weaker structure and becomes easily damaged and dislodged. This genetic mutation can occur in cats naturally, but selective breeding for this trait since the 1960s has produced the Sphynx breed. Some Sphynx cats are completely bald, while others have short downy fur over their bodies or in isolated areas. ***CC***

TOBY GRAHAM, SHREWSBURY

HOW DOES WATER EVAPORATE WITHOUT BOILING?

Liquid water is made up of molecules of H_2O attracted to one another by intermolecular forces known as 'hydrogen bonds'. These are relatively weak, and there are always some H_2O molecules whizzing around with enough energy to break free of their neighbours, even at temperatures well below 100°C. These can then escape – 'evaporate' – into the air. Even more evaporation will take place if the surrounding air pressure is reduced, for example by going to high altitude. ***RM***

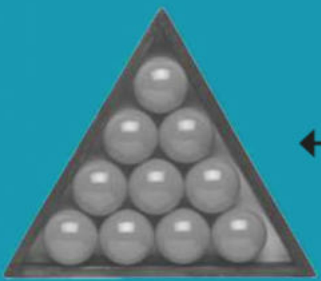
WHAT CONNECTS

GRETA THUNBERG AND SNOOKER?

1. Teenage climate activist Greta Thunberg has a beetle named after her. The beetle was found in Kenya in the 1960s but wasn't named as a new species (*Nelloptodes gretae*) until last year.

2. Thunberg has a long way to go to catch up with Sir David Attenborough, though. He has at least 20 species and genera named after him, including a beetle (pictured above), a carnivorous plant and an extinct marsupial lion.

3. Attenborough's TV career began in 1952, when he joined the BBC and started producing natural history series such as *Animal Patterns* and *Zoo Quest*. He later became controller of BBC Two.



4. When the BBC began broadcasting in colour in 1967, Attenborough showcased the benefits of colour TV by commissioning *Pot Black*, a programme featuring the, then relatively obscure, sport of snooker.

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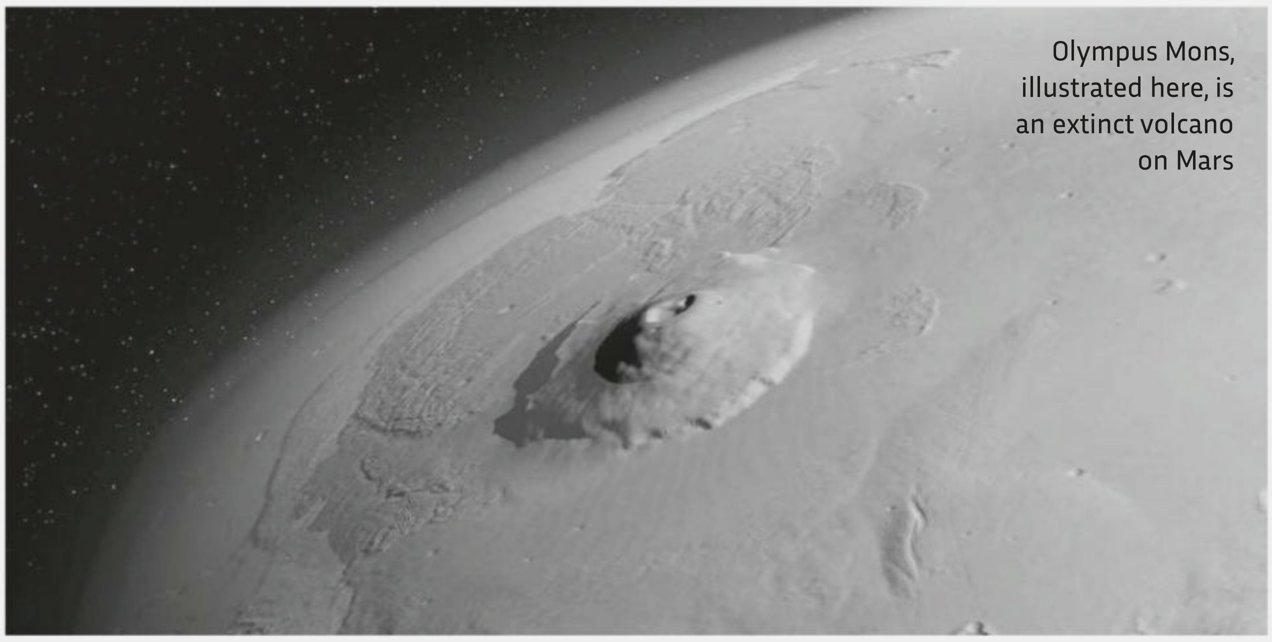
OLD WIVES' TALES...

YOU CAN CURE YOUR HICCUPS BY DRINKING FROM THE WRONG SIDE OF A GLASS

Hiccups are involuntary contractions of the diaphragm. These contractions cause a sudden inrush of air, slamming shut the leaf-shaped flap of cartilage in your throat known as the 'epiglottis' (this is what causes the 'hic' sound).

The documented cures for hiccups generally fall into three categories – raising the level of CO_2 in your bloodstream (holding your breath), stimulating the vagus nerve (sticking your finger in your ear – or anus!), and distraction (a sudden fright). The technique of drinking from the wrong side of the glass may be a combination of the last two: it requires you to concentrate on the task, and cold drinks stimulate the vagus nerve through the stomach wall. If you drink a large glass without stopping, you may even interrupt your breathing for long enough to affect your blood CO_2 levels too.

However, none of the folk cures for hiccups have good scientific research to back them up, and scientists don't understand the mechanisms that might be at work. Most studies are anecdotal reports of cures for patients with persistent bouts of 'intractable hiccups' that have gone on for months or even years, and it's possible that these have a different underlying cause. For more ordinary episodes of hiccups, there seems to be a large placebo effect at work – so as long as you believe in the cure, it will probably work. ***LV***



Olympus Mons, illustrated here, is an extinct volcano on Mars

JIMMY PHILLIPS, BRISTOL

WHAT'S THE TALLEST MOUNTAIN IN THE SOLAR SYSTEM?

Olympus Mons, an extinct volcano on Mars, is often quoted as the highest mountain in the Solar System, at a height of 21.9km (two and a half times the height of Everest). However, the mountain peak in the centre of the Rheasilvia crater on the asteroid Vesta, at about 22.5km, appears to be marginally taller. We don't know for sure because of difficulties in defining the mountains' 'base' heights, and uncertainties in measurements. ***AGu***

AMY-GRACE ENZER

HOW DO FISH END UP IN ISOLATED BODIES OF WATER LIKE LAKES?

Leaving aside the obvious answer that humans often deliberately introduce fish to lakes and ponds, we can draw a comparison with the population of isolated islands. Just as an island may once have been connected by a land bridge, so lakes may originally have been part of river systems that dried up. Or a river may have flooded long ago and briefly flowed into low-lying land to create a populated lake. Some lake residents are even descended from ancestors that crossed from one lake to another. While most fish can't travel very far over the land, their eggs will survive for several hours out of water. When waterbirds come to lakes to feed, fish eggs might get stuck to their feathers, hitching a ride to a new home. ***LV***

GETTY IMAGES X3, NIGEL SWALES ILLUSTRATIONS: DAN BRIGHT

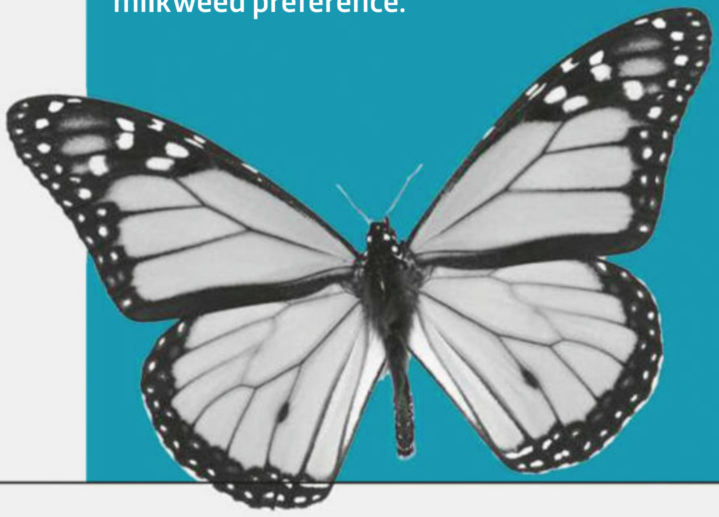
CROWDSCIENCE

We've teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

DO ANIMALS USE MEDICINE?

HOW DOES MEDICINE USE EVOLVE?

As with every evolved trait, it's down to natural selection. An animal that comes across a new behaviour that's beneficial in some way is more likely to survive and pass that behaviour on to its offspring. A nice example of this comes from monarch butterflies, the caterpillars of which only feed on milkweed plants. Monarch butterflies are often infected with deadly parasites, and infected female monarchs tend to lay eggs on milkweed species that have higher concentrations of parasite-killing chemicals called 'cardenolides'. Prof Jaap de Roode of Emory University in Atlanta, US, has shown that this can reduce levels of infection in the butterflies' caterpillars, and that uninfected monarch butterflies don't show the same milkweed preference.



WHAT KINDS OF MEDICINE DO ANIMALS USE?

There's growing evidence that animals are able to 'self-medicate' using a variety of plants and insects. Chimpanzees, for example, have been observed swallowing whole the rough leaves from *Aspilia* plants. These leaves are believed to brush parasitic worms from their gut wall, so that they can poo the worms out of their body. Meanwhile, more than 200 species of bird have been observed 'anting', where the birds rub ants along their feathers, or roll in ant nests. This could be another form of parasite control – the birds mostly use ant species that spray toxic formic acid. There's even evidence that African elephants self-medicate, eating a plant from the borage family in order to help induce labour.

WHAT CAN ANIMALS TEACH US ABOUT MEDICINE?

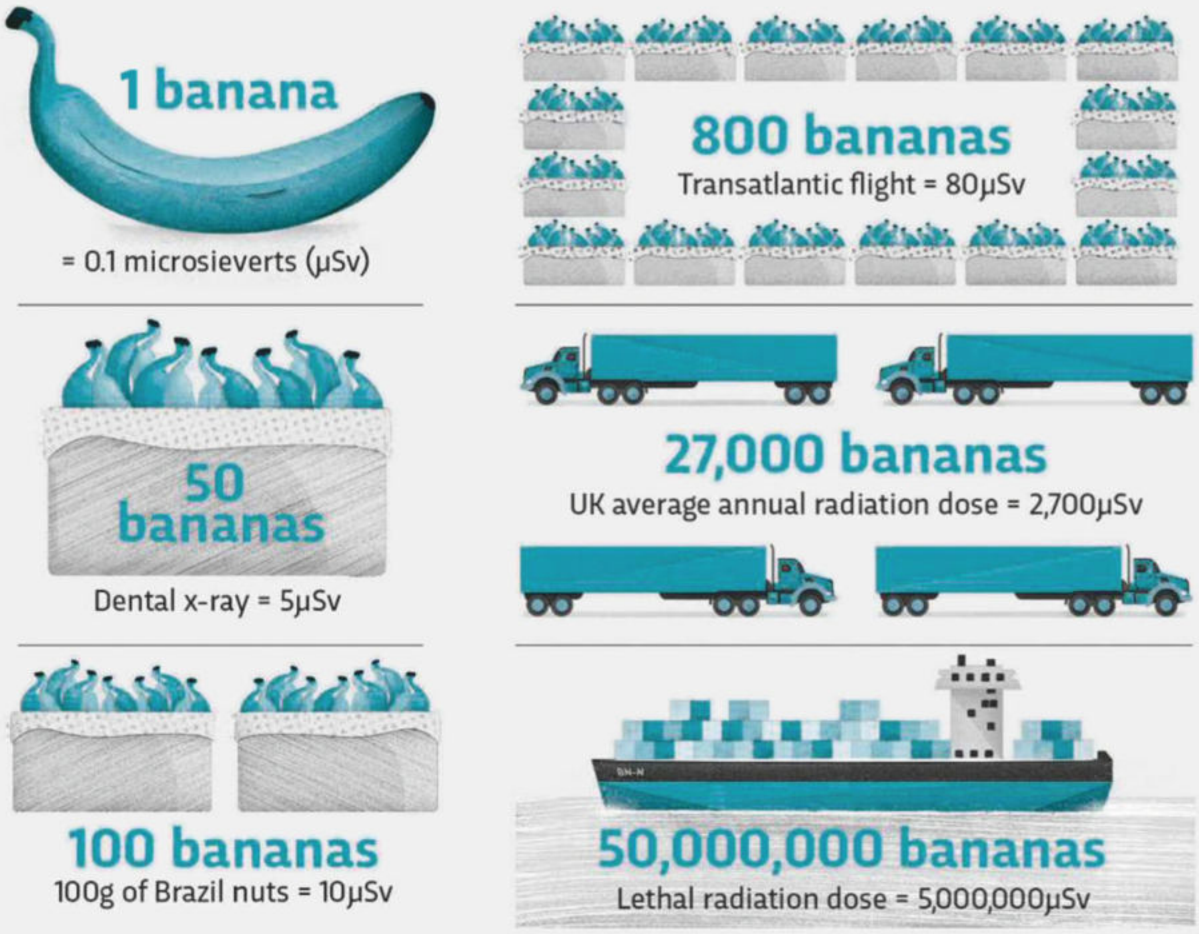
Myths and folklore often cite animals as the source of medical knowledge, and today's pharmacologists are increasingly looking to self-medicating animals for inspiration. The *Aspilia* plants used by chimps to flush out parasites have also been found to have antibacterial properties, so compounds extracted from these plants could help to treat infected wounds. Orangutans in Indonesia have been observed rubbing a foamy mixture of saliva and leaves from another plant, *Dracaena cantleyi*, on their body, and local indigenous people use this plant in a similar way to relieve joint and muscle pain. Scientific analysis of this plant has since shown that it does indeed have anti-inflammatory properties. The natural world, it seems, is full of healing compounds, and animals can help to point us in the right direction.

Rory Galloway is the producer of *How did humans discover medicine?* – an episode of *CrowdScience* that can be streamed at: **bbcworldservice.com/crowdscience**

JOHNNY PEREZ, VIA EMAIL

HOW MANY BANANAS WOULD I NEED TO EAT TO BECOME RADIOACTIVE?

Bananas are slightly radioactive because they are rich in potassium, and one of its natural isotopes (variants) is potassium-40, which is radioactive. A lorry full of bananas is radioactive enough to trigger a false alarm on a radiation detector looking for smuggled nuclear weapons. But you can't become radioactive by eating bananas, because you already are radioactive! A typical adult contains around 140g of potassium, of which about 16mg is potassium-40 – making you 280 times more radioactive than a banana. Eating one increases your total amount of potassium-40 by 0.4 per cent, which is detectable with a sensitive Geiger counter, but the effect is temporary since your metabolism closely regulates the amount of potassium in your body, and you will excrete the excess within a few hours. ***LV***


1 banana
= 0.1 microsieverts (μSv)
800 bananas
Transatlantic flight = 80μSv
50 bananas
Dental x-ray = 5μSv
27,000 bananas
UK average annual radiation dose = 2,700μSv
100 bananas
100g of Brazil nuts = 10μSv
50,000,000 bananas
Lethal radiation dose = 5,000,000μSv

NATURE'S WEIRDEST CREATURES...

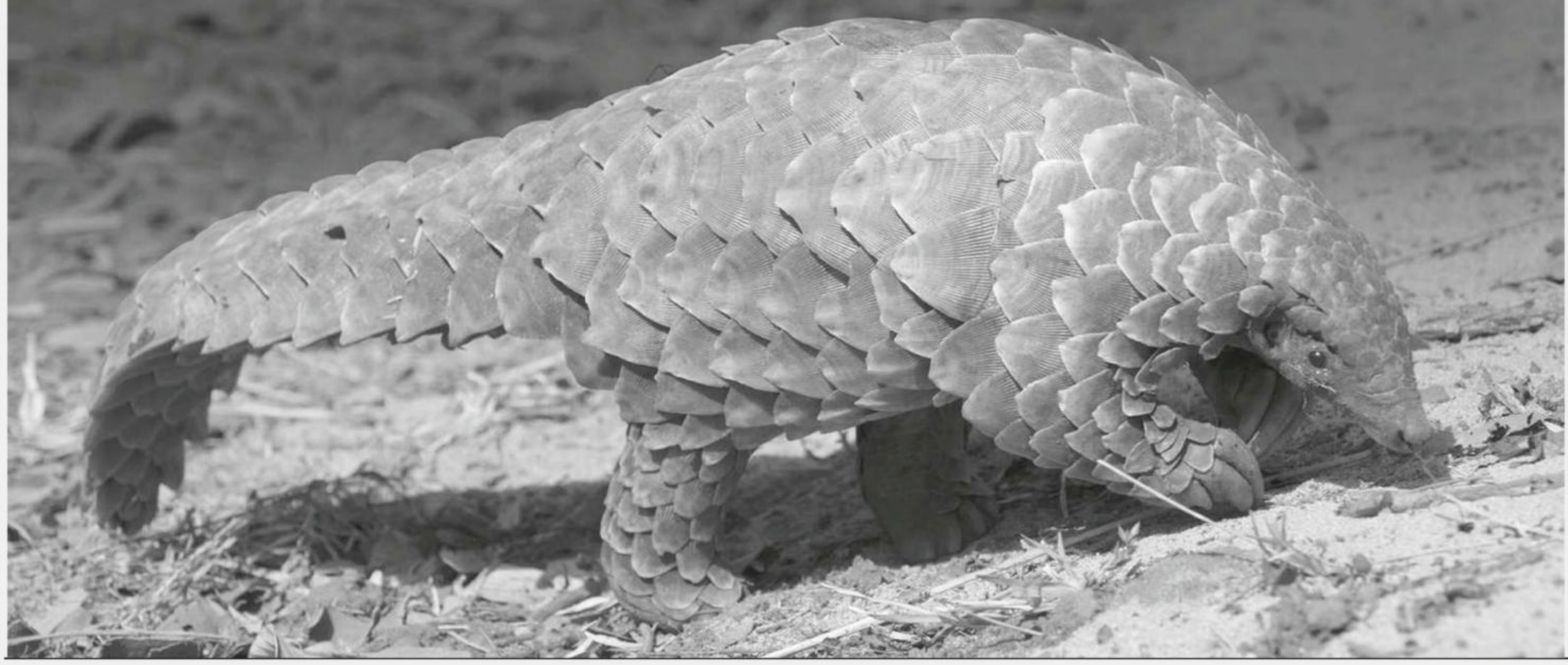
THE PANGOLIN

If an anteater and a pinecone had children, this is what they'd look like. The pangolin is the only mammal to sport an armour of scales. These sharp, overlapping plates cover the animal's entire body, apart from its snout and belly, and, when threatened, a pangolin will curl itself into a ball, helping to deter predators such as lions, tigers and hyenas.

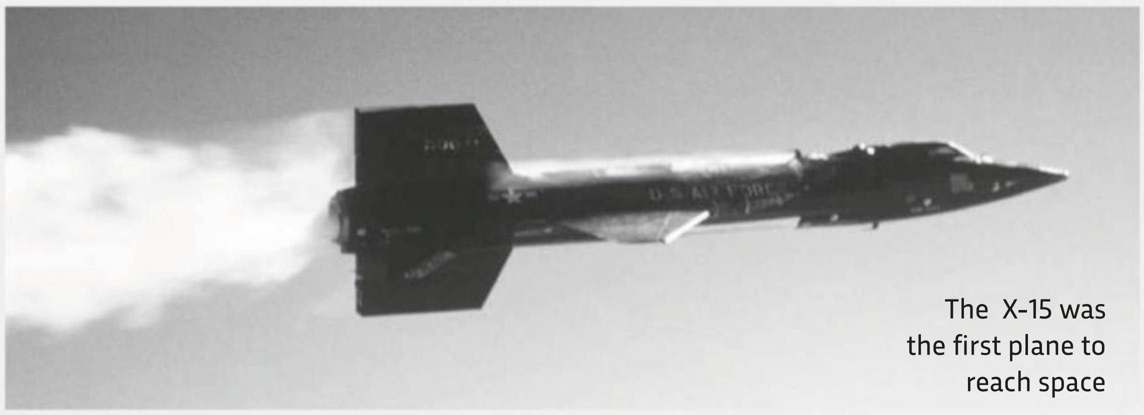
Pangolins don't have teeth. Instead, they feed on ants and termites using a sticky tongue which is rooted in the animal's chest and can be up to 40cm long – sometimes longer than the pangolin itself! Pangolins also swallow small stones, which help to grind up the insects inside their stomach.

Their powerful front claws are great for breaking into termite mounds, but rubbish for walking. There are few sights more appealing than the hunched figure of a pangolin scurrying along on its back legs only, like a dinosaur. Google it, I urge you.

There are eight species of pangolin. Four live in Africa; four in Asia. All are threatened, and pangolins are now the most trafficked animal in the world. They are poached for their meat, and for their scales which some think have medicinal qualities. But their scales aren't medicinal: they're made from keratin, which is the same protein that makes up hair, claws and horns. ***HP***



GETTY IMAGES X4 ILLUSTRATIONS: DAN BRIGHT



The X-15 was the first plane to reach space

DENNIS ROBERTSON, SHEFFIELD

WHY CAN'T WE FLY PLANES INTO SPACE?

Planes can and have flown into space for over 50 years – though not the kind you see at the airport. That's because conventional planes need air for both propulsion and lift, and space is essentially a vacuum.

The first plane to reach space was the X-15, designed in the mid-1950s for the US National Advisory Committee for Aeronautics (NACA), forerunner of NASA. It made its first flight in June 1959, using thin, stubby wings for generating lift and stability while travelling at over five times the speed of sound, plus a revolutionary form of rocket motor whose power output could be varied like a conventional aircraft engine. In 1963, an X-15 using a propellant of oxygen and ethyl alcohol reached an altitude of over 100km, widely recognised as the altitude at which space begins. The lessons learned were fed into the Space Shuttle programme and today's commercial spaceplane ventures like Virgin Galactic. ***RM***

JASON WEBB, TENNESSEE

WHY DOES SMELL AFFECT TASTE?

Strictly speaking, taste only occurs in the mouth, and refers to one of the five basic sensations detected by the taste buds – sweet, salty, sour, bitter and savoury or 'umami'. Your nose, however, detects aroma, which can identify a much wider range of thousands of volatile compounds. The sum of these two sensations is what we perceive as *flavour*, and so both play an important role in our overall experience of food. ***LV***

QUESTION OF THE MONTH

SACHIN SHAW, VIA EMAIL

IS THERE ANYWHERE THAT'S COMPLETELY BACTERIA-FREE?

Bacteria have colonised the planet more thoroughly than any other class of organism. They live 11km deep in the Pacific Ocean, and at altitudes of 40km, near the top of the stratosphere. There are bacteria that live in solid rock, metabolising radioactive waste, and even some that survive in boiling water. The incredibly dry Atacama Desert in Chile was once thought to be lifeless, but in 2006 scientists found bacteria there that take advantage of the minute amounts of moisture absorbed from the air by salty rocks. In our own environment, we can reduce the number of bacteria but not eliminate them entirely. One species has even evolved to survive the rigorous sterilisation process used in NASA clean rooms. In fact, probably the only place on Earth that we can be confident will always be entirely bacteria-free is the lava crater of an actively erupting volcano. *LV*

WINNER

Sachin wins a pair of Outlier Gold earphones, worth £94.99. These stylish earphones have 14 hours of playtime per charge, or 39 hours when coupled with the charge case. They are compatible with Apple Siri and Google Assistant, boast Super X-Fi audio, and are even sweatproof too. **uk.creative.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH

Hollywood science
We talk *Star Trek*, warp drive and transporters, with sci-fi consultant Dr Erin p100

Night lights
Capture the photogenic Moon-Venus conjunction this month p102

Reading list
Our pick of the best books hitting the shelves this month p102

Books that made me
Journalist and author Michael Mosley reveals his favourite books p103

FOR THE FAMILY

1

DISNEY+

Launched last year, the new Disney subscription service rivals platforms like Netflix and Amazon Prime. Stream your favourite films from Disney and Pixar, plus content from Marvel and National Geographic, both owned by Disney. The streaming service has been out in the US for some time now, so we're already excited about the chance to check out some of the exclusive Disney+ originals, including *Star Wars: The Mandalorian*, *The World According to Jeff Goldblum* and a live-action remake of *Lady and the Tramp*, as well as the beloved classics.

£5.99 a month or £59.99 a year

2

CAMBRIDGE SCIENCE FESTIVAL

The 26th Cambridge Science Festival looks to the past to predict a vision of the future. Expect fantastic exhibitions, workshops, talks, art and music.

9-22 March

3

HOWTHELIGHTGETSIN

Globe at Hay, Hereford

HowTheLightGetsIn brings philosophy, science and music to the banks of the River Wye, with 2020 marking the first dedicated Children and Young Adults' Programme. David Nutt explores the science and culture of recreational drugs and cosmologist Laura Mersini-Houghton asks if the Big Bang was really the beginning.

22-25 May

howthelightgetsin.org

4

CHILD OF OUR TIME: TURNING 20

Check Radio Times

For two decades, the team behind *Child of our Time* have documented the lives of 25 British children. Viewers have watched them grow from infancy, witnessed their struggles at school and burgeoning relationships as they navigated the change from teen to adult. Now, they are turning 20. In this *Horizon* special, archive footage has been pulled together to reflect on the lives of the children, now adults, for the final time.

DISNEY CHANNEL/IMAGE.NET, BBC X3, NASA X2, DAVID TETT PHOTOGRAPHY

5

RADIOACTIVE

Rosamund Pike plays Nobel Prize-winning scientist Marie Curie as she embarks on her groundbreaking journey, discovering radioactivity and changing the face of science forever.

In cinemas from 20 March

6

TIGERS: HUNTING THE TRAFFICKERS

Available on BBC iPlayer

There are fewer than 4,000 tigers left in the wild, with numbers still dropping as poachers hunt, kill and consume. In this documentary, former Royal Marines Commando Aldo Kane trains anti-poaching units, but be warned, this is not for the faint-hearted. Tiger cubs are kept in freezers at a breeding facility in Laos, while in Vietnam they are fattened and kept in cages to be killed and cooked to order.

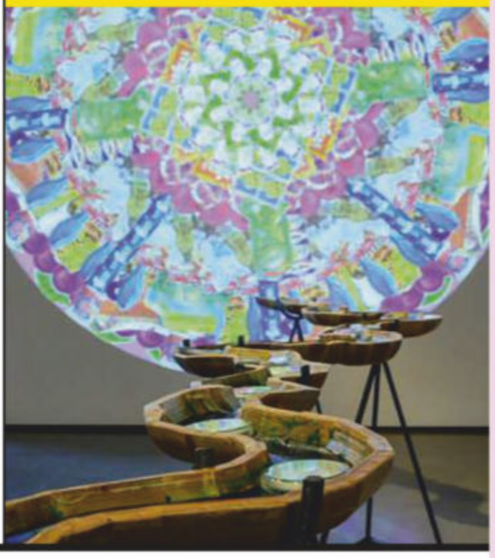
7

GENDERS: SHAPING AND BREAKING THE BINARY

Science Gallery London

GENDERS brings together artists and biologists, neuroscientists and activists, to demonstrate the diversity of gender. Class, culture, race, age and sexuality all play a part, but so too is science and tech transforming future ideas of gender.

On until 28 June



8

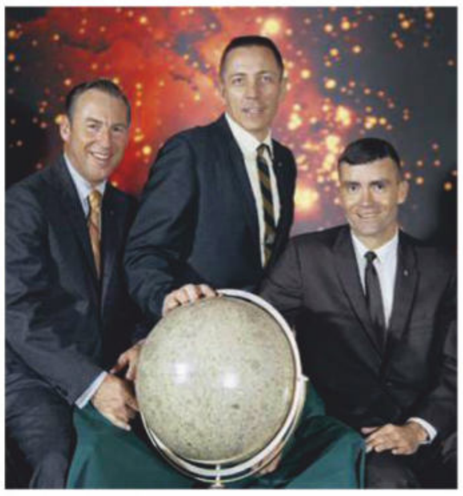
13 MINUTES TO THE MOON – SEASON TWO

BBC World Service

This season, listeners will hear the story of Apollo 13, the Moon landing mission that never was.

Episode one begins with the 'six minutes of silence', when the world held its breath to await radio contact from the Apollo 13 crew, who were re-entering Earth's atmosphere after spending four days on a ship severely damaged by explosion. Contributors to this season include Apollo 13 astronauts Fred Haise and Jim Lovell, with music by Hans Zimmer.

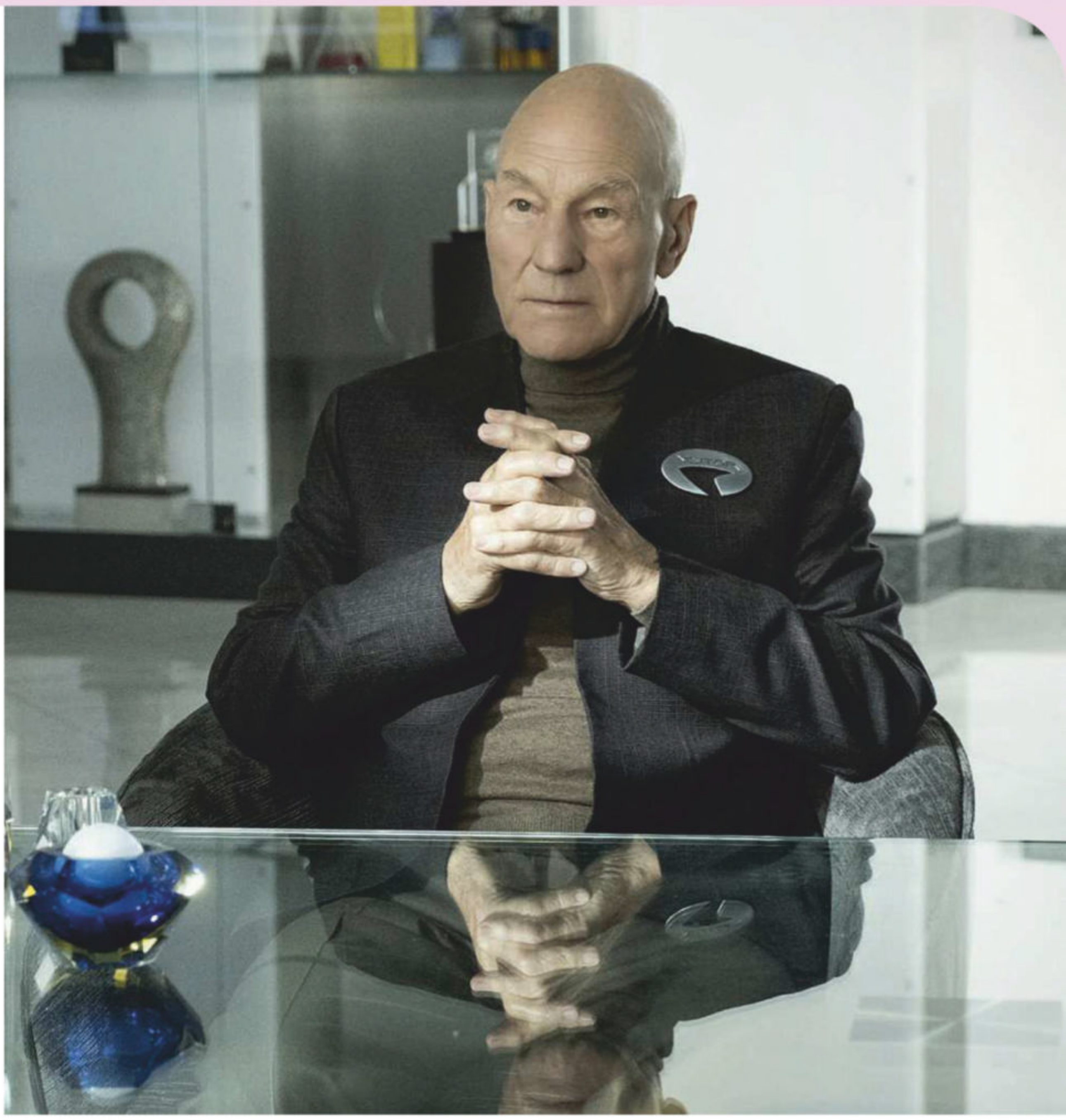
From 9 March



Profile

MAKING IT SO

STAR TREK'S NEWEST SCIENCE CONSULTANT, DR ERIN MACDONALD, REVEALS HER FAVOURITE TECH FROM THE SHOW AND EXPLAINS EXACTLY HOW FASTER THAN LIGHT TRAVEL _COULD_ THEORETICALLY WORK



> “Nothing with a mass on the surface of spacetime can go faster than the speed of light, but there’s nothing that says spacetime *itself* can’t go faster”

AS SCIENCE CONSULTANT FOR THE _STAR TREK_ FRANCHISE, WHAT DOES YOUR JOB INVOLVE?

Science is a big part of *Star Trek*, and my job involves reading scripts, talking to writers, talking to show runners, discussing the story arc and discussing episode to episode what type of technology they want to use, or what science is driving the story points. But I also continue to provide fan content. I have a video on StarTrek.com where I explain how warp drive works, and I’m due to be a guest on the *Star Trek: The Cruise*, where I’ll continue using *Star Trek* to teach science – the fans really enjoy that!

STAR TREK IN GENERAL SEEMS TO BE GETTING DARKER, DO YOU THINK THIS IS A RESULT OF OUR CHANGING PERCEPTION OF THE FUTURE?

You know, it’s interesting. I think a lot of people see *Star Trek* as this bright, shiny thing. If you go back to the original, there are some dark episodes, but it still has a very flashy, sci-fi feel to it. *Deep Space Nine* too, has story arcs that span seasons with very dark themes. So, I don’t think that the new episodes are necessarily darker, but I think the stylistic approach to the visuals makes it feel a little darker. As well, we’ve gone from being episodic storytelling to being serialised, where you’re telling one story over the course of 13-16 episodes. Take the Xindi War, or the Dominion War for example. If you took out all the standalone episodes, and turned it into one shorter season, it would feel very dark. We used to have a lot of filler episodes, and I love filler episodes! But that’s just not how we tell stories these days in general. Here in America, we’ve been doing 24-episode seasons for decades. Now, we’re starting to take out those fillers and tell one story over a shorter time. *Star Trek* has been reflecting the darker parts of society for a

AMAZON ORIGINAL
STAR TREK
PICARD
amazon prime video

STAR TREK PICARD
AMAZON PRIME & CBS ALL ACCESS

long time, and that goes back to the original series, but more importantly, in *Deep Space Nine* and *Enterprise*. It's interesting to see how storytelling has changed more than the types of stories that are being told.

IS THERE ANY TECHNOLOGY IN STAR TREK THAT YOU'D REALLY LIKE TO SEE?

Oh, warp drive is my number one! If we can go faster than the speed of light, our whole universe will open up. Faster than light travel is a necessity for most science fiction. Back in the movie *First Contact*, it was Zefram Cochrane testing out the first warp engine that caused the Vulcans to show up and induct humanity into the Federation.

DO YOU THINK WARP DRIVE IS THEORETICALLY POSSIBLE AND THAT WE'LL ACHIEVE IT BY 2063?

I think theoretically, mathematically, it is possible. The science behind the theory, is basically this idea that our universe is a 'sheet' of spacetime. Nothing with a mass, on the surface of spacetime can go faster than the speed of light – this is Einstein's Theory of General Relativity. At zero mass, you can coast along at a fixed speed, at the speed of light. But, there is nothing that says spacetime *itself* can't go faster than the speed of light. Warp drive is this idea that you can build a bubble of spacetime around your ship, and that bubble propels you faster than light. Our limiter is just our knowledge of spacetime itself. Imagine a bowling ball on a trampoline as an analogy for a mass on this sheet of spacetime – spacetime, our trampoline, will be curved. So, you can warp spacetime with a mass, but also an equivalent amount of energy – a lot of energy. The question we need to answer, is how much energy will get us from point A to point B – but the math at the moment is unclear, so I'm not sure we're on target for 2063, but I'll be the first champion!

IS BEING A SCIENCE CONSULTANT NOW, HARDER THAN IT WAS IN FOR EXAMPLE, KIRK'S DAY?

Oh, for sure. Sometimes writers will say, 'I don't need a science consultant, I have the internet'. And I don't blame them! Me coming in as a PhD in astrophysics to be a science consultant is kind of a hard sell, because of that exact point. I think a lot of writers have had bad experiences with science consultants, the consultant will just turn around and say 'no, that doesn't work. Sorry, science says no!'

But that's where I take a different approach, I'm not there to be a nay-sayer. I'm there to take an improv approach and say, 'All right, yes! You want to do this crazy time-travel story, let's see how we can make that work!' I'll make sure that they don't put anything 'wrong' in the script. And I love that. It eases the burden for the writers, I have a lot of knowledge already, but if I need to look something up, I know exactly where to look. I'm a sci-fi fan – as well as a scientist – so, for me, it's a dream job.

ARE THERE ANY CONCEPTS IN SCI-FI THAT ARE JUST NOT POSSIBLE?

As much as a lot of us want transporters, especially when we have to spend hours sitting in airports, it's really one of those physics-says-no situations, because of the Heisenberg Uncertainty Principle. For transporters to work, we would need to break down the body into all its fundamental components, then rebuild it somehow. This means you would need to know *exactly* where all your particles are, but Heisenberg's principle does not allow you to do that – you can't know exactly where subatomic particles are at any one point in time.

But what *Star Trek* did is brilliant, and this is the sort of thing I hope to bring to writer's rooms in the future. They have a component in transporters called the Heisenberg Compensator, and they don't say anything more than that. But for us science geeks, we're like, 'oh, ok, so they compensate for Heisenberg's principle somehow'. I love it when science fiction does that. As long as they're not saying anything wrong when they try to explain it.

DR ERIN MACDONALD

Erin is Science Consultant for the Star Trek franchise, holding a PhD in Astrophysics. She has an online series "Dr Erin Explains the Universe" and her specialty is general relativity.

Interviewed by** BBC Science Focus **production assistant Holly Spanner

DISCOVER MORE

Subscribe to the Science Focus Podcast *and listen to our full interview with Dr Erin Macdonald.*

sciencefocus.com/science-focus-podcast

DR ERIN'S TOP SHOWS (THAT AREN'T *STAR TREK*)

FIREFLY

(2002 2003)

My love for this show runs so deep, I get emotional just hearing the theme song. The 'Verse is a place that feels so real, the characters are like family to us. It also resulted in my all-time favourite board game, *Shiny*.

X-FILES

(1993 2018)

This is what started it all for me, it had everything I loved. Seeing a red-headed women fight aliens with logic and science - she was everything I wanted to be, and resulted in me wanting to study physics.

FUTURAMA

(1999 2013)

My physics professor actually made me watch this as a contingent for being his research student! You can tell physicists and mathamaticians were involved in the writing by the amount of nerdy easter eggs there are!

AMAZON PRIME VIDEO

RECOMMENDED

WHAT'S CAUGHT OUR ATTENTION THIS MONTH

by ***Amy Barrett***

EDITORIAL ASSISTANT

Thanks to this month's reality check, p34, I know our best guess is that it'll be around 100,000 years before Betelgeuse goes supernova. But the star *has* been dimming, so why not take this opportunity to look to the night skies and spot its orange glow, forming what we see as the left shoulder of the constellation Orion.

Towards the end of the month, we'll be treated to a fantastic photo opportunity – on 28 March, look up to see a waxing crescent Moon, the bright light of Venus, and the open cluster of stars called the Pleiades, in what is known as a Moon-Venus conjunction.

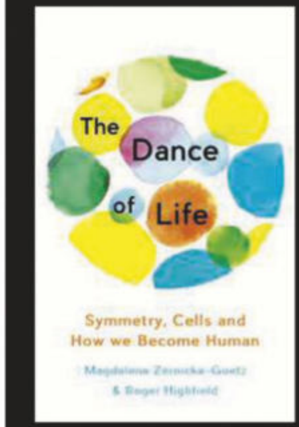
There's plenty to watch and listen to on the BBC this month – see p3 and p98 for some of our favourites – but I'll definitely make a point of listening to the second series of ***Changing World, Changing Bodies*** on BBC Sounds. Produced by Kevin Mousley for the BBC World Service, this three-part series will look at how modern life has changed our relationship with sleep, how our height has more impact on our success than we might have thought, and the populations who outlive the rest of the world and why.

The city of Bristol (where the *BBC Science Focus* team work their magic) will host the ***Bristol Festival of Ideas*** in March. Communications officers, scientists and policymakers question how we should think about the future with writer Margaret Heffernan, while Gaia Vince, science and environmental journalist as well as award-winning author, discusses how our social culture and our love for the beautiful played a huge part in human evolution.

> "At the Bristol Festival of Ideas, scientists and policymakers will question how we think about the future with Margaret Heffernan"

READING LIST

NEW BOOKS TO THUMB THROUGH

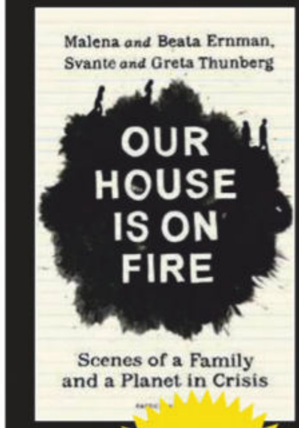

The Dance of Life
Symmetry, Cells and How we Become Human
Magdalena Zernicka-Goetz & Roger Highfield

THE DANCE OF LIFE

MAGDALENA ZERNICKA-GOETZ AND ROGER HIGHFIELD

£18.99, WH ALLEN

Magdalena Zernicka-Goetz studies mammalian development and stem cell biology, and when pregnant, found her baby may have had a chromosomal mutation. *The Dance of Life* is a deeply moving story intertwined with the science of human development, research into solving IVF disorders, preventing miscarriages and life's beginning.


Malena and Beata Ernman, Svante and Greta Thunberg
OUR HOUSE IS ON FIRE
Scenes of a Family and a Planet in Crisis

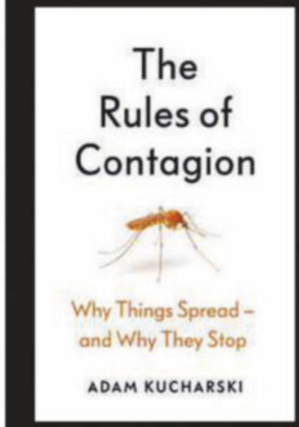
EDITOR'S CHOICE

OUR HOUSE IS ON FIRE

MALENA AND BEATA ERNMAN, SVANTE AND GRETA THUNBERG

£12.99, ONEWORLD

How does a teenager become the head of a global climate change campaign? In a series of scenes, Malena Ernman tells the story of how her daughter, Greta Thunberg, shot to fame. She describes their family and experiences leading up to that seminal day when Greta sat outside the Swedish parliament to protest climate inaction, and their lives changed forever.



THE RULES OF CONTAGION

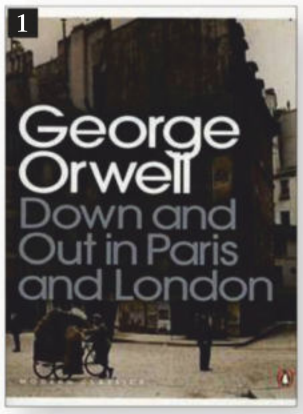
ADAM KUCHARSKI

£16.99, WELLCOME COLLECTION

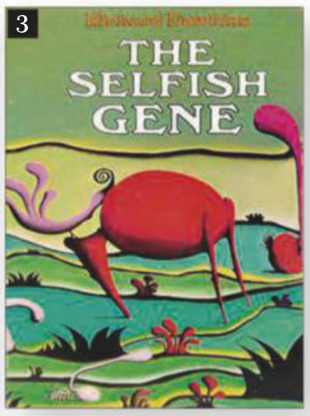
From infectious diseases to financial crises, viral social media posts to technological innovation, epidemiologist Adam Kucharski shows how scientists are using maths to predict and contain contagion, and why some outbreaks still take us by surprise. *The Rules of Contagion* expands further than just media headlines. "What about the outbreaks that never happen at all?" asks Kucharski.

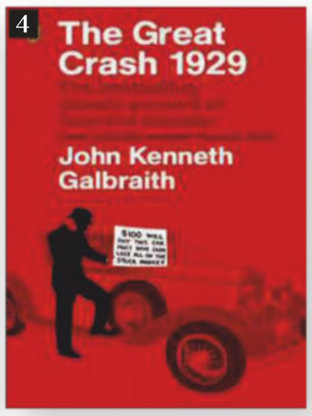
THE BOOKS THAT MADE ME: DR MICHAEL MOSLEY

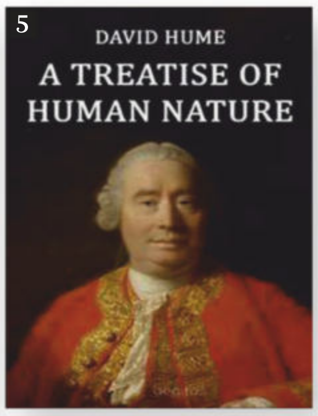
DR MICHAEL MOSLEY IS A FAMILIAR FACE ON BBC TELEVISION AS A PRESENTER ON *TRUST ME, I'M A DOCTOR* AND *HORIZON*. YET HE ALSO HAS A SLEW OF BOOKS UNDER HIS BELT, INCLUDING *THE CLEVER GUTS DIET*, *THE FAST DIET* AND THE *8-WEEK BLOOD SUGAR DIET*. HERE ARE THE BOOKS THAT INSPIRED HIM...

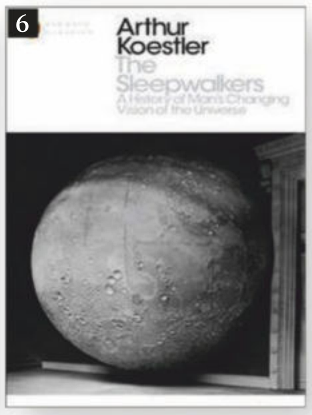


2
Emma
JANE AUSTEN









I originally went to Oxford to study politics, philosophy and economics. I became a banker, before moving into medicine, and some of these books influenced that decision.

I've read all of George Orwell's books many times, but my favourite is ***Down and Out in Paris and London***, which is just really funny. I thoroughly enjoyed *1984* and *Animal Farm*, but I enjoyed his journalism more. *Down and Out in Paris and London* is an insight into taking someone from a privileged background and transposing them to rougher parts of the world. Since I came from a very privileged background, I like the idea that it's Orwell who first introduced me to the idea of becoming a journalist. He puts himself at the heart of the story, which is something that I've done with my programmes by self-experimenting.

An author I came to quite late was Jane Austen. I love Jane Austen, I think she's insightful and witty. It's difficult to choose a favourite, but I'd probably go with ***Emma***. Emma is a very sparky and bright woman. I loved her as a character, the fact that she's always certain but frequently wrong was quite charming. I was in my teens when I read it, trying to understand women, and I found Jane Austen helpful.

Next up would be Richard Dawkins's ***The Selfish Gene***. It's a classic because he makes you think about the world in a completely different way. It's interesting, because Dawkins doesn't use his own original research, but rather weaves together other people's. That's what I've tried to do, weaving other people's academic research together into a more popular narrative.

Then, John Kenneth Galbraith's ***The Great Crash***. He's the guy who introduced me to economics. I originally wanted to study maths, but when I read Galbraith I thought, "Golly, that's interesting," and changed my mind. I read a lot of philosophy but another writer I like is David Hume. He wrote ***A Treatise of Human Nature***, and is recognised as probably the greatest British philosopher, but few have heard of him. He inspired Adam Smith, and people like Darwin. He's a sceptic and an empiricist, so he's very keen on looking at the foundations of knowledge. He's sort of the founder of cognitive science. He just writes really well – you have to read it several times before you understand it though! He's been a huge influence.

The last one is by Arthur Koestler, ***The Sleepwalkers***. It's about how science progresses not in a rational sense, but in strong leaps and bounds. One thing that unites all these writers is the idea that human behaviour is governed by emotion, rather than reason. And that really shows you the power of human emotion. Galbraith said the great crash was perpetuated by stupidity and fear, things like that. Hume's biggest thing was that human behaviour is driven by emotion and we should recognise that. And Jane Austen's *Emma* is a very smart cookie but makes numerous mistakes – she thinks she's making rational decisions but she's just completely wrong. She tries to matchmake based on what she thinks is reasonable, but it just turns out that she has misunderstood things.

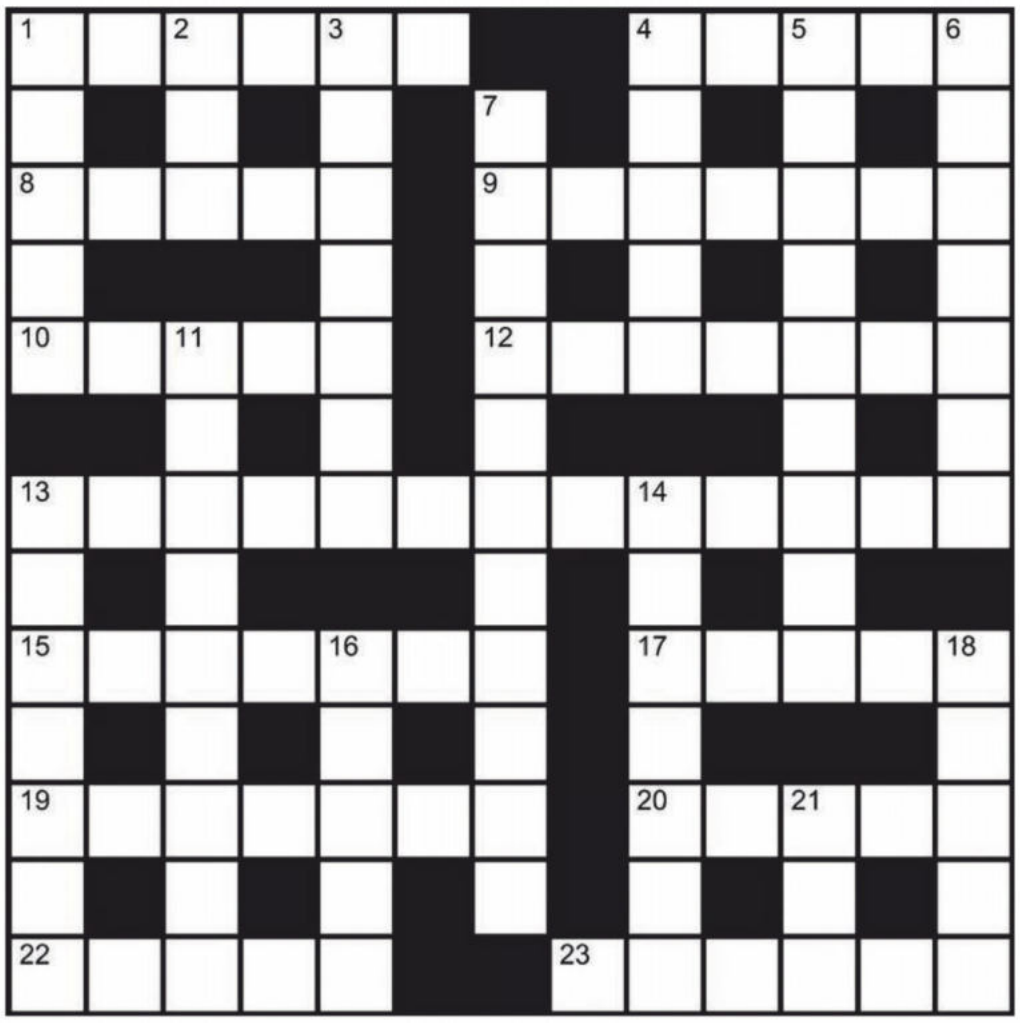
> "One thing that unites all these writers is that human behaviour is governed by emotion, rather than reason. And that really shows you the power of human emotion"

by **DR MICHAEL MOSLEY**
(@robinince)

Michael is a science presenter and author. His latest book is The Clever Guts Diet *(£8.99, Short Books).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Some wine for a Republican in bistro (6)
4 Pasta turned out to be Spanish food (5)
8 Eavesdrop on heartless guy in infantile conveyance (5)
9 Old vehicle Ian exchanged for an instrument (7)
10 Rota devised by a vital supplier (5)
12 Allow space to put heading (7)
13 Boyfriend in favour of adjusting castle for wind level (8,5)
15 Bagel constructed by artist in system using symbols (7)
17 Finally doesn't finish a book (5)
19 Sketch notes for conscript (7)
20 Heard quiet composition (5)
22 New road, new element (5)
23 Surface temperature on Mars, say (6)

DOWN

1 Snake finds a place in Whitehall (5)
2 Equipment for soldier back after run (3)
3 Travel a bit as a rugby player (3,4)
4 Land treatise (5)
5 Game is inapt – ruined party (9)
6 Setting around a lake forms a triangle (7)
7 Cryptologist caught poem with a wave (11)
11 Defender right to argue about a road (9)
13 Bishop takes steps to find an organ (7)
14 Small demand around edges of palace for a knife (7)
16 Stick to prohibition outside (5)
18 Reportedly posted some perfume (5)
21 One played for a very long time (3)

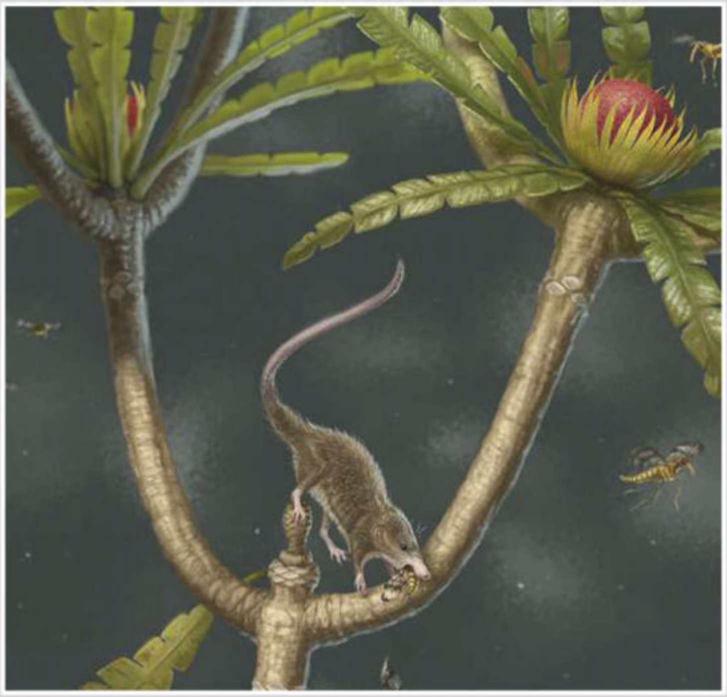
ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

THE SECRET LIVES OF ANCIENT MAMMALS

We know the dinosaurs died out when the asteroid hit. But what were the planet's furrier animals doing back then?



GETTY IMAGES

PLUS

DNA DETECTIVES

The new tech helping to solve old crimes.

INTERVIEW: DR PRAGYA AGARWAL

HUBBLE'S HIDDEN GEMS

Enlightening images of the cosmos.

ON SALE 8 APR

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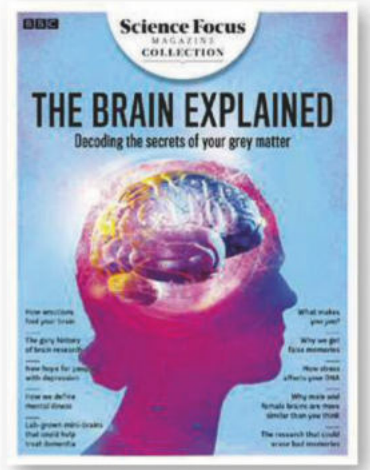
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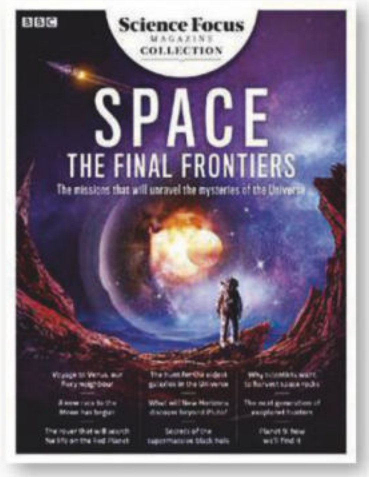
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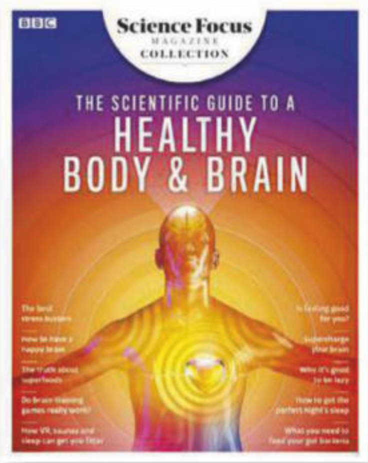
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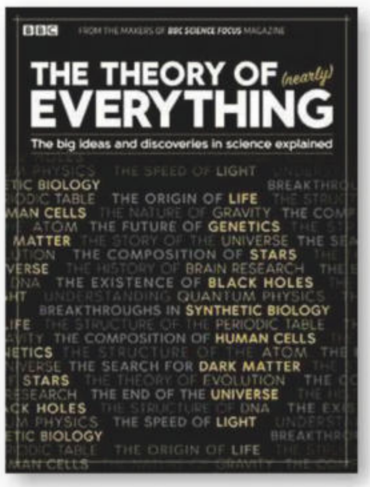
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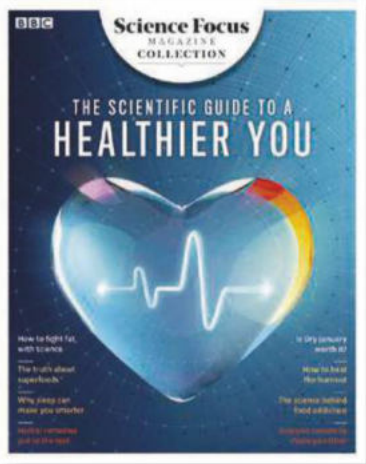
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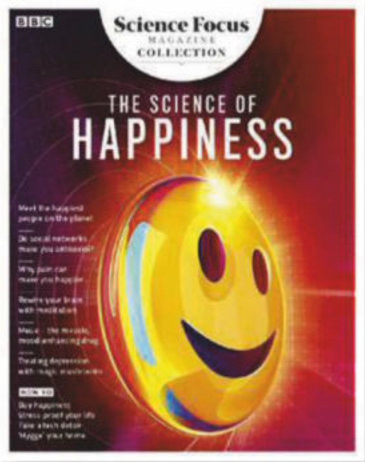
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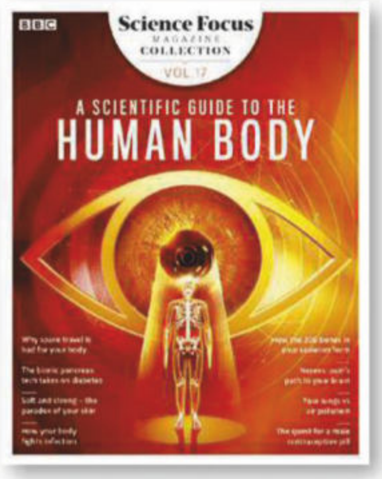
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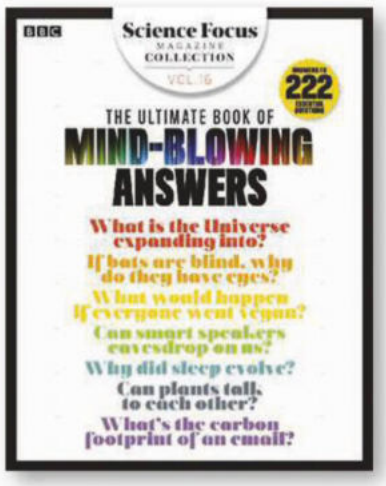
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A SCIENTIST'S GUIDE TO LIFE

HOW TO COPE WITH YOUR PERIOD

IT'S TIME TO TALK ABOUT 'THAT TIME OF THE MONTH'. MENSTRUAL RESEARCHER **SALLY KING** TACKLES HOW TO DEAL WITH YOUR PERIOD

WHAT'S THE BIGGEST MYTH ABOUT PERIODS?

That the menstrual cycle repeats itself regularly every 28 days. This is the average length, but there's a huge healthy range, from 21 to 40 days, and the length typically varies by two to four days each time. It's a problem because people whose periods don't fit into a 28-day pattern can feel like there's something wrong.

WHY DO SOME PEOPLE GET SUCH HEAVY PERIODS?

Average menstrual blood loss is about 30ml to 45ml, or two to three tablespoons per period, but again there's a range. Technically, anything over 80ml is considered heavy. It's thought there is a genetic component. Annoyingly, anaemia can also trigger heavier periods, creating a vicious cycle!

IS IT A GOOD IDEA TO TRACK PERIODS WITH AN APP?

I think everybody should track their cycle for a while to see what's normal for them. If you have symptoms, it can help your GP to determine if they are related to your cycle or not, and spot signs of other problems. It's worth saying that cycle tracking alone is not an effective form of contraception!

WHAT THINGS DOES MY MENSTRUAL CYCLE AFFECT THAT I MIGHT NOT REALISE?

Many chronic health conditions can be triggered or worsened at certain points in the cycle, including migraine, epilepsy, allergies and food intolerances. Asthmatics may find they are wheezier at certain times in their cycle. These connections are well established in clinical research, but they haven't yet passed into clinical advice for patients.

WHAT'S THE BEST WAY TO DEAL WITH PERIOD PAIN?

Anti-inflammatories, like ibuprofen, really help. Not many people realise this, but the time to start taking ibuprofen is two to four days before you expect to start your period. If you do this, it not only reduces cramping, it also reduces the amount of blood you lose. This can make a big difference for people with painful, heavy periods. Magnesium supplements can help, as can more traditional approaches like exercise and hot water bottles.

IS IT OKAY TO TAKE PILL PACKETS BACK TO BACK TO AVOID A PERIOD?

Yes. It may not always prevent bleeding, but it will reduce it. There's this idea that if you don't have a regular bleed that you're somehow accumulating toxins or hormones. This isn't true. The lining of the womb just doesn't build up as much in the first place.

IS IT A GOOD IDEA TO TAKE A BREAK FROM THE PILL?

If you're on the pill and doing well, there's no reason to have a health break. Some people worry that the pill can damage future fertility, but this isn't true. It can take time to get pregnant after coming off the pill but most people regain their natural cycle after three to four months. SF

SALLY KING

Sally is a researcher at King's College London, and founder of Menstrual Matters, an evidence-based information hub. ***Interviewed by Dr Helen Pilcher.***

NEED TO KNOW...

1. Don't worry if your cycle is not 28 days. This is only the average.

2. There's no need to take a break from the pill if you're happy with it and doing well.

3. Ibuprofen not only helps with pain of cramps, it can also reduce blood flow.

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